Dr. Robert Bell

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH.

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER;
R. W. BROCK, DIRECTOR.

MEMOIR No. 6

GEOLOGY

OF THE

HALIBURTON AND BANCROFT AREAS

PROVINCE OF ONTARIO

BY

FRANK D. ADAMS, and ALFRED E. BARLOW

OTTAWA
GOVERNMENT PRINTING BUREAU
1910

Price 30 cents.

No. 1082

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH.

HON W. TEMPLEMAN, MINISTER; A. P. LOW, DEPUTY MINISTER;
R. W. BROCK, DIRECTOR.

MEMOIR NO. 6

GEOLOGY

OF THE

HALIBURTON AND BANCROFT AREAS

PROVINCE OF ONTARIO

BY

FRANK D. ADAMS, and ALFRED E. BARLOW

OTTAWA
GOVERNMENT PRINTING BUREAU
1910

Price 30 cents.

No. 1082

To R. W. BROCK, ESQ.,

Director Geological Survey,

Department of Mines,

Ottawa.

SIR,—

We beg to submit the following memoir on the Geology of the Haliburton and Bancroft areas, Province of Ontario.

We have the honour to be,

Sir,

Your obedient servants,

Signed { **Frank D. Adams,**
Alfred E. Barlow.

Montreal, May 27, 1908.

CONTENTS

ILLUSTRATIONS

Photographs.

Drawings

Maps.

FRONTISPIECE.

PLATE I.

Laurentian Peneplain, looking northeast from lot 22 on concession line between II and III, township of Hagarty, Golden lake in distance.

GEOLOGY

OF THE

HALIBURTON AND BANCROFT AREAS, PROVINCE OF ONTARIO.

BY

Frank D. Adams, and Alfred E. Barlow.

PHYSICAL FEATURES OF THE AREA.

The general character of the surface of the area embraced by the two map sheets accompanying this report is constant throughout its entire extent, and forming as it does, a portion of the great Canadian Shield, or Northern Protaxis of America, its features are those presented by this great region in most other places. Here the country is a great plain, rendered somewhat uneven by depressions worn in its surface, and which are now occupied by a great number of lakes and streams. The name peneplain may be applied to it, although this term implies that it has originated from long continued processes of sub-aerial denudation. In how far these processes have contributed to the formation of the plain, and in how far they may have been assisted by marine erosion, is a question which is as yet uncertain, and which it is not our purpose here to discuss. While, therefore, the term peneplain is a convenient one to apply to this great stretch of country with its distinctive physiographic features, it may perhaps be more accurately designated simply as a somewhat dissected plain. From the surface of the plain, in a few places, there rise low, rounded hills or monadnocks, forming pronounced features of the landscape. (See Frontispiece and Plate II.)

Owing to the depressions, and the hills in question, the country presents to the casual observer a rolling or hilly character, but that it really is a plateau or elevated plain, which has been etched or dissected by the agencies of decay and erosion, is evident from a study of the landscape as seen from any of the higher

points in the area, as, for instance, from the summit of Greens mountain, on lots 15 and 16, concession I of the township of Glamorgan, which is 1,466 feet above sea-level, and from which an uninterrupted view of the surrounding country can be obtained in all directions as far as the eye can reach. The sky-line from here is seen to be flat and even around the whole horizon, its uniformity being broken only by three or four low hills, rising from the plain in different directions. To the north and west the sky-line appears absolutely flat. The hills constituting the unevennesses in the sky-line are, like Greens mountain itself, composed of masses of harder rock, which remain by virtue of the resistance which they offer to erosion. Thus the most noticeable of the little humps on the sky line, as seen from Greens mountain, is a group of hills composed of granite, which form part of the Anstruther batholith, and are situated on concession V of Monmouth. Another is formed by a ridge of dioritic rock, which is crossed by the Monck road in the eastern portion of the same township. Another slight unevenness in the sky-line is caused by a granitic mass north of McCue lake, in the same township. The same even sky-line is well seen from the higher points in the central and southern parts of the township of Anson, or from any of the higher elevations in the townships of Dysart, Harburn, or Bruton. It is also very distinctly seen from the Hastings road, just south of McKenzie lake, on the line between the townships of Lyell and Wicklow. In the southern part of the area embraced by the Bancroft sheet, the same even sky-line, broken only by a very few low isolated hills, can be observed from the top of the Blue mountains in the township of Methuen, or from the higher points in the great dioritic intrusion occupying the central portion of the township of Lake.

Although, however, when viewed from any particular point, this plain appears very even, its surface is not quite horizontal. From the southwestern portion of the area the plain rises gently, on going north, until an area of maximum elevation is reached, beyond which it slopes gradually down toward the north, or northeast again. This area of maximum elevation is situated near the northern boundary of the Haliburton sheet, entering the sheet about the southeastern corner of the township of Peck, on the height of land between the Madawaska and Muskoka rivers (1,506 feet above sea-level), and following a direction somewhat

PLATE II.

Laurentian Peneplain, looking east from Fort Stewart, township of Carlow.

south of east through the townships of Lawrence, Eyre, Clyde (southern part), crosses the line between McClure and Sabine, through Wicklow into Bangor. This constitutes the watershed of the region, the waters from it being carried off to the south in a number of small rivers, into large lakes, which lie to the south and west, beyond the limits of the maps, and thence into the St. Lawrence; while along the northern slope it is drained by a number of little streams, which unite to form the Madawaska river. This river, following along the northern slope, runs around this higher portion of the plain to the east, and, passing through the townships of Radcliffe and Raglan, gathers up all the drainage of the eastern margin of the area embraced by the Haliburton sheet, and, flowing through the township of Lynedoch, eventually reaches the Ottawa.

The heights of all the points in the area whose elevations have been determined—some 120 in number—have been recorded on the map sheets. These are taken for the most part from White's *Altitudes in Canada*, but some are the result of special barometric measurement. The elevations being chiefly of points along lines of railway are naturally somewhat lower than they would be for adjacent points on the surface of the plain, the railways naturally following, as far as possible, lines of depression.

The average height of the plain, as a whole, in the area covered by the Haliburton sheet, may be taken as about 1,250 feet above sea level. In the higher tract referred to above and forming the watershed, it is about 1,500 feet. So far as known, the highest point in the area is on the Hastings road, about six miles north of Maynooth, in the township of Wicklow, which was determined barometrically to be 1,570 feet above sea level.

To the south of the limit of the Haliburton sheet, in the southern portion of the Bancroft sheet, the plain continues to slope gently to the south, and eventually passes beneath the Palæozoic strata which here border it. The lowest points in the whole district are along this contact, Stony lake being only 768 feet, and Deer bay 793 feet above sea level; while the roadbed of the Central Ontario railway, which, crossing concession XIV of Tudor, is 1,035 feet above sea level, sinks to 944 at Millbridge station, and to 828 at Bannockburn station, four miles and a-half farther south, just beyond the margin of the Bancroft sheet.

The average gradient of the southward sloping portion of the plain cannot be certainly determined with the data at present available, the exact height of a sufficient number of points not being known. If, however, a line is taken from the height of land which here forms the divide between the Muskoka and Madawaska rivers, at the northern edge of the Haliburton sheet in the township of Peck (1,506 feet), in a direction S. 19° E. to the surface of the plain at a point two miles south of Gooderham (1,213 feet), in the township of Glamorgan—a distance of 46 miles—the gradient will be found to be 6·4 feet to the mile. If a longer line is taken, crossing the entire area considered in this report, running a little to the west of that just mentioned and parallel to it, from Canoe lake in the township of Peck (1,379 feet), just north of the limit of the Haliburton sheet, to Deer bay (793 feet), in the township of Harvey, at the extreme southern limit of the Bancroft sheet, the total descent will be 586 feet, and the gradient 8·1 feet to the mile.

These figures probably represent very closely the average southerly gradient, except along the easterly margin of the area, where the plain, as shown above, has a more uniform elevation from north to south.

The plain, as has been mentioned, presents by no means a perfectly even surface. It has been etched by the agents of erosion, and is thus pitted and scored. In these depressions lie the lakes, which are so abundant in the area, or in some cases swamps, and the streams and rivers which connect and drain them. The accentuation of the country is, however, very low, and it is very seldom indeed in any part of the area that the hills whose summits represent the plain rise as much as 250 feet above the waters of the lake or river at their foot. In by far the greater number of cases the difference in level is much less than this. The greatest difference in level of any two points on the Haliburton sheet, so far as known at present, is 639 feet, the highest point being that north of Maynooth, referred to above, and the lowest being the surface of Lake Kamaniskeg, in the township of Bangor. If the depth of the waters of this lake were added to the figure given above, the maximum difference in level to be found in the Haliburton sheet would probably be obtained.

At some points in the area, as has been mentioned, isolated hills, or small groups of hills, forming notable features in the landscape of the surrounding district, rise above the general sur-

face of the plain. These, as has been mentioned, are usually composed of some more resistant rock and survive on account of the greater resistance which they offer to the action of the forces of denudation. One of these already mentioned—Greens mountain—on lots 15 and 16, concession I of Glamorgan, rises 1,466 feet above sea-level, or 253 feet above the level of the surface of the surrounding plain, and is composed of a massive gabbro. Another, made up of syenite, is known as the Blue mountain, and is situated in the central part of the township of Methuen. It is, at its highest part, 300 feet above the surface of Kasshabog lake, which lies immediately south of it, or about 1,100 feet above sea-level. Its height above the plain, in a shallow depression of which the lake lies, would thus be somewhat greater than that of Greens mountain, although its height above sea-level is considerably less.

Along the southern margin of the area also, conspicuous hills are formed by the isolated outliers of the horizontal Palaeozoic strata of the great plain of central Canada, which bounds the Archaean country on the south. These Palaeozoic strata formerly completely covered this Archaean country, along its southern portion at least the surface of what we may term the Archaean plain being seen to pass beneath them. Now that the strata in question have been almost entirely stripped off, and the underlying Archaean (or pre-Palaeozoic) plain is once more laid bare, these surviving remnants of the Palaeozoic stand up from the surrounding Archaean country as steep-faced hills, composed of horizontally bedded limestones, and which can be seen for long distances.

We thus have the old and somewhat eroded and uneven plain, presented by the Archaean rocks, passing beneath a more even plain formed by the surface of the Palaeozoic. The question of the relation of the surface of this latter plain to the higher elevations in the Laurentian area, whether or no they once formed part of it; as well as the question as to whether, in the Laurentian area itself, the lack of horizontality is to be considered as caused by warping, or as due to two or more plains of erosion of different date partially superimposed one upon another, can only be settled by a very detailed topographical study of this area, and of that lying both to the north and south of it.[1]

[1] Wilson, A.W.G.: The Physical Geography of Central Ontario. Trans Can. Inst. (Toronto), vol. vii, 1900-01, p. 145.

The data accumulated for the discussion of these problems is not as yet sufficient for their solution. The existence of two base levels in the northern portion of the Adirondack region, which is a southerly continuation of that described in the present report, has been discussed by Cushing[1]. Some portions of the Adirondacks are much more highly accentuated than others. "In the eastern Adirondacks the altitude and relief are considerable, with little sign of that concordance in altitude which might reasonably be expected in such an old land area, as marking periods of rest between the various uplifting movements which the region has undergone. In St. Lawrence county, in the western Adirondacks, the numerous hills and ridges do not attain very coincident altitudes, and strongly suggest a peneplain, with occasional monadnocks rising above the general level."[2] The plain is almost everywhere more or less mantled by drift, the ice of the glacial period being the latest agent of erosion. The thickness of this drift varies considerably in different places. Over the greater part of the area it is comparatively thin, so that while it forms the soil of the country, the underlying rock, in the form of smooth roches moutonnées, protrudes through it at frequent intervals, giving ample opportunity for a study of the petrographical character, and the structure of the rocks beneath. In some districts, however, the drift is heavier, and forms an almost continuous covering, no exposures being visible for long distances. Such an area is that forming the northwestern corner of the Haliburton sheet, and traversed by the road from Dorset to Tea lake—a great, rolling, drift-covered expanse. An undulating sheet of drift also covers the southern portion of the township of Sabine, stretching across the northern portion of McClure, Wicklow, and the southern half of Lyell. In this area scarcely any exposures of the underlying Laurentian can be found. Areas of heavy drift are also found in the northern portions of the townships of Dysart, Anstruther, and the southeastern part of Carlow. The drift in these stretches of country, and generally everywhere at the higher levels throughout

[1] Prel. Rep. on the Geology of Franklin county, pt. 3, 18 Ann. Rep. of the State Geologist of New York.

[2] Report of the Director of the N.Y. State Museum and State Geologist 1900, page r 27.

PLATE III

Surface of moraine, 2 miles east of Ingoldsby, northeast corner of the township of Snowdon

the area, is unstratified and filled with boulders, the stratified gravels and sands being found about the lakes, and in the river valleys. The drift undoubtedly gives to the plain a somewhat smoother surface than it would present were the surface freed from drift, although the accentuation of the country is probably not decreased by its presence, to any considerable extent; for, while the drift undoubtedly fills many depressions in the subjacent rock surface, it also mantles and thus increases the elevation of many of the highest parts of the area. When the drift is very thin and disconnected, or when, as in a few places, it is absent, the country assumes a very rocky and barren aspect, great expanses of bare roches moutonnées surface extending in every direction. Such tracts are almost exclusively confined to certain developments of granite or diorite, as for instance those crossed by the Buckhorn road in the township of Glamorgan, or by the Hastings road in the townships of Wollaston and Limerick. Similar drift-free areas are seen in the great Blueberry Barrens in southeastern Methuen, as well as in the diorite and granite areas of Cashel and Grimsthorpe. The thinness of the drift sheet, or the absence of drift, in the case of the granitic or dioritic areas, is due in part to the fact, that being composed of rocks which offer a marked resistance to erosion, these areas stand at relatively high levels, while most of the other rocks of the district, being somewhat softer, are apt to form the depressions in the plain, and are there likely to be more or less covered by drift. This cause, however, by no means determines the distribution of the drift in all cases, for, as has been shown, many great stretches of granite, forming the higher portions of the area, lie under an almost continuous mantle of drift.

One of the most characteristic features of the landscape of this region, as of most other parts of the great northern protaxis in Canada, is the immense number of lakes, large and small, which stud its surface. Some 525 lakes occur in the area of 4200 square miles embraced by the two map sheets which accompany this report, or one lake to about every 8 square miles of surface. These lakes range in size from comparatively large bodies of water, like Hollow lake, which has an area of about 22 square miles, down to very small lakes or ponds, which cover only a small fraction of a square mile. These lakes are filled with beautifully clear and fresh water, and discharge through

the multitude of streams and little rivers, which, with them, constitute the drainage system of the district, and along the course of which are many beautiful waterfalls, supplying ample power to mills at various points. By means of these hundreds of lakes and their connecting streams, it is possible, if the routes be known, to traverse the area in canoes in almost any direction, without making portages of any great length. Thus, there is a good canoe route from Gull lake, in the southeast corner of the area, northward through the township of Minden to Whitney on the line of the Grand Trunk railway, about the middle of the northern margin of the Haliburton sheet, and thence south through Baptiste lake to Bancroft, the terminus of the Central Ontario railway. From thence there is a canoe route to the northeast, down the York branch of the Madawaska, to the limits of the sheet. While thus it is often very difficult, except for the experienced woodsman, to traverse the forests of the unsettled parts of the country on foot, the district is admirably suited for canoe travel, and by means of canoes access may be had to any part of it.

The lakes, which are so numerous in this tract of country, occupying, as has been shown, shallow depressions in the plain, are in some cases true rock basins, and in other cases depressions in the mantle of drift. Other lakes have banks which are in part rock and in part drift, occupying, in some instances, portions of a rock basin which has been partitioned off, or partly filled up by a mass of drift.

As examples of lakes occupying rock basins, Rock lake, in the township of Livingstone, and most of the lakes in the township of Lawrence may be cited, the surrounding rock being the gneissic granite, which underlies such a great expanse of country in the northern part of the Haliburton sheet. The granite can be seen to form a continuous rim about most of these lakes, rising from them to heights of 100 to 150 feet. Another striking example of a rock basin is that occupied by Clear lake, in the southeastern corner of the township of Sherbourne. Still other excellent examples are afforded by Compass lake and Stoplo lake, situated in the granite country forming the western side of the township of Burleigh. This tract of country is free from drift, and consists of a series of low ridges of granite running with the strike of the gneiss, in the depressions of which lie

little lakes. Another peculiar example is to be found in a narrow lake, nearly two miles long, crossing concessions XII, XIII, and XIV on the west side of the township of Lutterworth, this lake depression being remarkable in that it cuts directly across the strike of the gneisses in which it is excavated, throughout its whole length.

As an instance of lakes which lie in depressions in the drift, the two lakes situated on lots 25, 26, and 27, of concessions X, XI, and XII of the township of Harcourt, may be cited. These lie in a sandy pine flat, which has an elevation of only a few feet above their waters, and which is continuous with that through which the branch of the Madawaska draining these lakes flows, both to the north and south of the lakes in question. Another lake about which very little rock is exposed, and which may be said to occupy a drift depression, is Clearwater lake, in the township of McClintock. Oxtongue lake, in the same township, as well as Beech and Maple lakes, in the township of Stanhope, are in like manner almost entirely bordered by drift. Head lake, by the side of which the village of Haliburton is situated, and many other sheets of water in the area, have no rock exposed about their margins.

Furthermore, it can be clearly seen from the surface features of the country, that, in many cases, groups of these lakes which are now separate sheets of water were at one time connected. The low flats of stratified sand which separate them are clearly portions of the lake bottom when the water stood at a somewhat higher level than at present, while the higher land, which formed the original lake shores, can be seen in the background bordering the plain.

Thus, in the southern portion of the township of Dysart, Head lake, Grass lake, and the little lake immediately to the south of the latter sheet of water, were at one time connected with each other, and with Lake Kashagawigamog. In the same way, Drag lake formerly extended to the southwest across the sand flat on concessions IV, V, and VI of Dysart, to Long lake, on concession IV, and thence to Blue Hawk lake, on concession I of Dysart. Drag lake was thus formerly at least twice as large as it is at present, and probably extended to the west from Blue Hawk lake, down the valley of the Burnt river, which would give it a still larger area. Welcome lake, also in the southern corner of the township of Nightingale, was formerly a portion of Pen

lake, which lies a mile and a half farther east, there being a valley connecting the two lakes, crossed by a great ridge of stratified gravelly drift, which dams back Welcome lake and forms a portion of its southeastern shore. Many other similar instances may be observed in all parts of the area.

The drift, however, is comparatively thin everywhere, and the depressions in its surface probably in many cases mark equivalent depressions in the surface of the underlying gneiss, and thus a glance at the Bancroft sheet—or, still better, at the Haliburton sheet—shows the remarkable influence which the strike of the rocks underlying the area has had upon the distribution, position, and shape of the lakes, and upon the course of the streams. In the southern portion of the area the lakes lie very largely along the course of the bands of Grenville limestone, while in the granite region of the north they form a delicately etched pattern on the surface of the great plain of granitic gneiss, occupying shallow depressions, whose course is determined chiefly by the strike of the country rock; and even when the lake runs across the strike the long arms and bays in its deeply indented shore line will be found to follow the direction of the strike.

The group of lakes in the townships of Nightingale, Clyde, Sabine, and Lawrence show in a striking manner how the shape of the lakes is determined by the complicated twisting of the strikes in that district.

The whole area was originally covered by a dense forest growth, consisting chiefly of pine, spruce, hemlock, and coniferous trees, but which in certain tracts, especially in the southern portion of the area, were replaced by maple, birch, or other hardwood bush. It is consequently a district in which immense quantities of timber have been cut, and which still contains large supplies. The green forest still covers by far the larger part of the region, although in many places forest fires have caused widespread destruction. In the southern and eastern parts, however, where the country is best suited for cultivation, the forest has given place to farms, and a large agricultural population has settled, which year by year is gradually encroaching upon the bounds of the forest, and extending the area of cultivated land.

GEOLOGICAL STRUCTURE.

The area embraced by the Haliburton and Bancroft sheets is occupied almost exclusively by Archæan rocks, and is one which, while presenting great complexity of structure, is at the same time of the highest interest. While it is impossible, on account of the intense metamorphism to which the area has been subjected, to determine the origin of every rock type which it contains, it may be said to present a great series of sedimentary rocks of very ancient date, with subordinate igneous intrusions, resting upon and invaded by an enormous development of granite, and granite-gneiss.

To the southeast the sedimentary series is largely developed, and is comparatively free from igneous intrusions. Toward the northwest, however, the granite, in ever increasing amount, arches up the sedimentary series, and wells through it in the form of great batholiths, in places disintegrating it into a breccia composed of shreds and patches of the invaded rock, scattered through the invading granite, until eventually connected areas of the sedimentary series disappear entirely, and over hundreds of square miles the granite and granite-gneiss alone are seen, holding, however, in almost every exposure, inclusions which represent the last scattered remnants of the invaded rocks.

The type of structure presented by the invading granite is that of a batholith. This term was introduced into geological nomenclature by Suess, to designate great lenticular-shaped masses of granite and other plutonic rocks, which have invaded the bedded or schistose rocks of the deeper portions of the earth's crust, and intruded themselves between the strata, arching these up in the same manner as laccoliths, and sending apophyses into them. These deep seated laccoliths, which are often of enormous dimensions, Suess[1] believes to have been formed by the passage of the granite into pre-existing cavities in the earth's crust, formed by the opening up of the strata under great differential pressure.

[1] Das Antlitz der Erde, vol. i, p. 219 (1885).

The term, however, has since its introduction been employed in somewhat varied senses by other writers. Suess[1] himself has more recently stated his definition of the word batholith in terms of the theory of intrusion. His definition may be freely translated thus: "A batholith is a stock-shaped or shield-shaped mass, intruded as the result of fusion of older formations (orig. *Durchschmelzungsmasse*), and on the removal of its rock cover, and on continued denudation, this mass either holds its diameter or grows broader to unknown depths (orig. *bis in die ewige Teufe*)." The name was invented to describe those largest of all intrusions, generally granitic, which are characteristically found in great mountain ranges, including the Central Granites, Intrusive Mountain Cores, and Fussgranit. The name has since been commonly used for bodies of intrusive rocks with the general characteristics of stocks, but of much larger size than is generally attributed to stocks or bosses. Daly recommends the use of the term in this sense, and proposes that the name batholith be given to any stock which has an area of over 200 square kilometers[2].

In the present report, however, the term batholith is used in the sense in which it was employed by Lawson in his classic work on the Lake of the Woods and Rainy Lake districts of Canada, to designate great lenticular-shaped, or rounded bosses of granite or gneiss, which are found arching up the overlying strata through which they penetrate, disintegrating the latter, and which possess a more or less distinct foliation, which is seen to conform in general to the strike of the invaded rocks when these latter have not been removed by denudation.

In these occurrences there is no evidence of the existence of sedimentary strata below the batholith, and it is clear from a variety of considerations, as will be shown, that the granite material did not force its way into cavities already opened to receive it.

These batholiths are well shown on the maps accompanying the present report. In this area they have a general trend in the direction of N. 30° E., which is also the direction in which the area is folded.

[1] Sitzunsberichte der Wiener Akademie, vol. civ. (1895.), p. 52.
[2] See Daly—The Classification of Intrusive Bodies. Jour. of Geol., vol. xiii, No. 6 (1905).
Loc. cit. p. 505.

Enumerating the batholiths in the southern portion of the area, passing from west to east, there is first, the great batholith running through the townships of Snowdon and Glamorgan, which may be referred to as the Glamorgan batholith, and which a few miles to the south of the limit of the Haliburton sheet, beyond the town of Kinmount, passes beneath the flat-lying Ordovician strata.

The limestone series sweeps around this batholith, separating it from the Dysart batholith to the north, and from a most interesting line of batholiths to the east.

This latter consists of a lineal series of four batholiths, the most southerly of which the Burleigh batholith comes out from beneath the flat-lying and much more recent Ordovician strata of the township of Harvey. This is almost cut off from the second by a constriction of the surrounding sedimentary series at Eagle lake, which series, although partly disintegrated by the intrusion, nearly meets across it on the line of this body of water. This second batholith of the series, which may be termed the Anstruther batholith, is a large and typical one, and is separated by a narrow but continuous belt of the invaded rock from the third batholith, which lies in the townships of Monmouth and Cardiff. This latter is connected by a very narrow arm of granite with the fourth batholith of the series, which, however, has only partially freed itself from the rocks which roofed it over, and which is itself centred about Deer lake, in the township of Cardiff. A very small amount of additional erosion would convert this series of batholiths, which are arranged like beads on a string, into one long, narrow batholith, resembling the Glamorgan batholith, to which reference has just been made.

The course of the strike of the rocks along the north shore of Stony lake shows that the Harvey batholith, a portion of which passes beneath the waters of this lake, is really connected with another large batholith, which runs up through the whole length of the township of Methuen, into the southwest corner of Wollaston. The actual connexion of these two batholiths, however, cannot be traced, on account of the fact that the waters of Stony lake cover the intervening area.

To the east of this Methuen batholith, in this southern portion of the area, although there are three small granite intrusions, no other batholithic mass is met with until the extreme eastern

border of the area is reached, which border is formed by the western margin of a great batholith in the township of Grimsthorpe. This, lying as it does almost entirely in the country to the east of the area of the map, has not been made the subject of a detailed study.

The granite of the batholiths, while in some places massive, usually displays a more or less distinct foliation. This, around the borders of the batholiths, coincides with the outline of the mass, and hence with the strike of the surrounding rocks. The chief exception to this rule is afforded by a portion of the eastern flank of the Anstruther-Burleigh batholith, to which reference has already been made, where the curving strike of the gneiss is abruptly cut off by a fault. Within the batholiths themselves the strike of the foliation follows sweeping curves, which are usually closed and centred about a certain spot within the area of the batholith, where the foliation becomes so nearly horizontal that its course, or even its existence on a flat surface is difficult to recognize. From these central areas of flat-lying gneiss, the dip of the gneiss where it can be determined is generally outward in all directions. The batholiths, therefore, are undoubtedly formed by an uprising of the granite magma, and these foci indicate the axis of greatest upward movement, and those along which the granite magma has been supplied most rapidly. Thus, in the Anstruther-Burleigh batholith there is one of these foci about lots 23, 24, and 25 of concession X of the township of Anstruther, and probably a second, though less pronounced one, about Sucker lake in the southwest portion of the same township, with a third about the middle of concession VI of the township of Burleigh.

In the great northern development of gneissic granite where the sedimentary strata have been removed by denudation, except so far as they exist in the form of included fragments, the same sweeping curves are seen, in some cases closing about certain centres; but in other cases, in the form of great curves, which pass beyond the limits of the map. The rule that the curves present an outward dipping foliation and centre about areas of more rapid uplift, although true in almost all cases, has a few exceptions. Thus, on the eastern side of the township of Lawrence, there is an area where the foliation of gneiss is horizontal. The foliation, both to the east and to the west of this area, dips easterly at low angles, while the strikes converge and sweep around

it to the south. This area, therefore, about which the strike of the foliation curves back upon itself, is one of local flattening of the dip.

So also in the southern portion of the area where the penetrated rocks still remain surrounding the batholiths. In the case of the Anstruther batholith, which is one of the linear series of four batholiths which has been already mentioned, the invaded rocks dip away from the batholith almost everywhere around its whole periphery. In the next—nearly circular—batholith, lying to the northeast of that just mentioned, and occupying the country on the boundary line of the townships of Cardiff and Monmouth, the attitude of the surrounding rocks is in places vertical, while elsewhere they dip away from the granite, the attitude in still other cases being uncertain. All along the southern and southeastern border of the Glamorgan batholith the invaded rocks dip away from the granite, while elsewhere around its periphery these rocks, being squeezed between this and the adjacent batholiths, are too highly contorted, and in some places too heavily drift-covered, to display the prevailing dip distinctly. In the case, however, of the Methuen batholith, the surrounding rocks, where the dip can be determined, are found in almost all cases to dip inward toward the invading granite gneiss. The same is true of the batholith in southern Chandos, which has its centre in the south bay of Loon lake. These masses have evidently eaten their way up into downward sagging portions of the overlying sedimentary series. In these batholiths the granite is almost massive. In all cases, however, where the uprising granite rock has developed a foliation, this conforms to the course of the border of the batholiths, and thus to the strike of the surrounding rocks.

It is interesting to note that the area embraced by the accompanying maps shows batholiths in all stages of dissection. Thus, the dome composed of limestone and amphibolite, on the apex of which Duck lake, in the middle of the township of Chandos, is situated, has evidently been arched upward by a subjacent mass of granite forming the core of the batholith, which granite, however, has not yet been reached by erosion. In the Monmouth-Cardiff batholith, a central granite area, with its surrounding zones of limestones, etc., is laid bare. In the Anstruther-Burleigh batholith the erosion has gone to a depth which is just sufficient

to render confluent what at a higher level were evidently two distinct batholiths, as shown by the central constriction of the mass, and the presence in the granite, along this line of constriction, of an immense number of fragments of the overlying cover, which was evidently once continuous across, and separated the two masses of granite in question. In the great northern granite area, the structure of the granite at greater depths is revealed, with its sweeping curves of flow, indicating the movements of the magma, of which the batholiths proper are the upward expression and development.

The batholiths, as has been mentioned, are elongated or arranged in lines having a prevailing direction of about N. 30° E., to which direction the strike of the rocks lying between the batholiths in general conforms. This direction constitutes, so to speak, the general strike of the country, and shows that its present structure has been determined not only by the rise of the granite magma, but by the presence of a second factor in the form of a tangential pressure, acting simultaneously and in a general northwesterly and southeasterly direction. If this district presents the basement of a former mountain range now planed down, the direction of this mountain range was about N. 30° E., or in a general way parallel to the course of the valley of the St. Lawrence.

The movements in the granite, to which reference has been made, did not take place solely while the rock was in the form of an uncrystallized or glassy magma. They continued during crystallization, and in many cases after crystallization was well advanced, but before the complete solidification of the rock. Evidence of protoclastic structure can be seen throughout all the areas coloured as granite or granite-gneiss on the maps, except in the cases of a few small bodies of granite of apparently more recent age, to be referred to later on. This clastic structure is seen in the presence of more or less lenticular-shaped, broken fragments of large individuals of the feldspar, in a fluidally arranged mosaic of smaller allotriomorphic feldspar grains, with quartz strings and a few biotite leaves. This fluidal arrangement which constitutes the foliation of these rocks, is almost invariably developed, and there is an imperceptible gradation from the perfectly massive forms occasionally seen, through the less and more gneissic varieties which constitute the chief part of the occurrences.

to thinly foliated gneisses. It is impossible to separate the several varieties. They constitute progressive developments of one and the same magma, and are different phases of one and the same rockmass.

The granite-gneiss is undoubtedly of igneous origin, and is very uniform in its mineralogical composition, differing distinctly from the sedimentary or paragneisses of the area. A detailed description of its several varieties, together with the evidence for the statements made concerning e character of the movements which it has undergone, are presented in the special chapter which deals with these granites and granite gneisses.

The movement of the granite magma appears to have been slow and uniform. No evidence of violent catastrophic action is found. The invaded rocks are, of course, penetrated by pegmatite dikes, which in some cases fairly swarm through them, indicating that while the rocks were ordinarily sufficiently plastic to yield to the deforming influence of the rising magma, the limit of this plasticity was sometimes exceeded: the fissures so formed being filled with pegmatite, which represents the la surviving portion of the granite magma. By this movement, when the invaded rock has been thoroughly broken and penetrated in all directions by the granite, its fragments can be seen to have slowly separated from one another, and to have drifted away in the moving granite. A swarm of separated fragments, in cases where the movement has not been too great, can often be clearly seen to have originally formed a portion of one and the same mass, the position and outlines of the several fragments being such that, if brought together, they would fit into one another.

As indicated on the map, in certain places on the Bancroft sheet, the granites have so completely broken up areas of the invaded rock, and so thoroughly penetrated them, that there has resulted a breccia, consisting of immense swarms of fragments, great and small, composed of amphibolite, limestone, etc., usually more or less angular, scattered through the granite, sometimes somewhat softened and elongated, and frequently altered, or even partially dissolved and incorporated by the granite magma. A well defined occurrence of this kind is seen in the district about Burleigh Falls, in he southwest corner of the township of that name; also along the southern portion of Kasshabog lake, in the

township of Methuen, and about the South Bay granite batholith, n the township of Chandos, as well as in many other places.

At the extreme north end of the Glamorgan batholith the granite passes into a more basic phase, which is referred to as a dioritic rock on the Bancroft sheet. This is a differentiation product of the granite magma, possibly resulting in part from the solution of the invaded rock. A specimen taken from the side of the mass nearest the granite, on lot 27, concession XV of Glamorgan, was found to be practically free from quartz, and to hold a little hornblende in addition to the biotite contained in the granite. This particular variety, however, is a syenitic rather than a dioritic rock since orthoclase is still the preponderating feldspar.

Folding.—As has been mentioned, in the southeast portion of the area, where the sedimentary strata are most continuously developed, the district being comparatively free from the granitic intrusions which elsewhere complicate the geological relations, the strata everywhere dip at a high angle. This angle is seldom less than 45°, and is generally considerably higher, but varies from place to place. A fine section across the sedimentary strata is afforded by the Hastings road. Along this, starting from the southern margin of the Bancroft sheet and going north, the limestone series, which is at first blue in colour, gradually loses its colour, strings of white, coarsely crystalline calcite being developed in it by a process of recrystallization, appearing in strings, or in some cases, in the form of irregular patches, more particularly along the bedding planes of the rock; while the harder siliceous bands which are interstratified with the limestone become more coarsely crystalline, and develop gradually into bands of typical sedimentary gneiss (paragneiss) or amphibolite, according to the original chemical composition of the band. On approaching the batholiths in the northern part of the area, this change becomes progressively more marked and striking, and eventually the blue limestones, by a process of complete recrystallization, pass into an enormous development of a more or less impure white marble.

Where this sedimentary series is invaded by the granite batholiths already described, it becomes more intensely folded, owing to the fact that it dips away from the batholiths, or sags down between them, the strike following the sweeping curves along which the sedimentary series seeks to adjust itself to the

outline of the invading masses. This structure is well shown on the geological maps which accompany this report.

The most complicated foldings met with in the area are those which are seen to the east of the great Anstruther and Burleigh batholiths, in the district where the four townships of Chandos, Anstruther, Methuen, and Burleigh meet. Here the sedimentary series is flanked by the Anstruther and Burleigh batholith on the west, and by the Methuen batholith on the east, while a third, though smaller batholith, whose centre lies in the South bay of Loon lake, cuts up through the middle of the belt, and running off to the southwest beneath the strata, causes the strike of the latter to bend back upon itself in a well marked V-shaped curve; while the granite holds an immense number of fragments of the invaded rocks.

One of the most striking results of this folding is a long syncline, which can be traced for fifteen miles, running approximately in a north and south direction, whose axis can be followed from lot 8, concession VII of the township of Burleigh, in a somewhat sinuous course to lot 1, concession XI of Chandos, beyond which it develops into a line of fault. To the east, this is succeeded by an anticline, whose axis, taking a somewhat convergent course, can be traced from the rear of concession IV of Anstruther, through concessions III, II, and I, on lot 39, into lot B of the Fraction of Chandos. Farther east the strata become folded along an east and west axis, to conform to the mass of the Loon Lake batholith.

To the north of Loon lake the strata assume a much more nearly horizontal attitude. In the district about Duck lake, on concession XI of Chandos, the underlying granite, here invisible, constitutes a buried batholith, the strata dipping away from the lake on every side, having a distinct quaquaversal attitude. The limestone cover, however, remains intact, denudation not having progressed sufficiently to lay bare the underlying granite mass.

To the northeast of this, along the road running between concessions XIII and XIV of Chandos, as far as the east side of the township, and for a mile and a half in the succeeding township of Wollaston, there is a tract of country, which is about a mile and a half wide, over which the strata display a series of gentle undulations, being often nearly flat. Vertical sections show in places intercalated sheets of amphibolite, in all probability representing

altered basic injections. This is the most extensive area underlain by strata having an approximately horizontal attitude which is found in the district embraced by this report.

The folding seen on a large scale in this sedimentary series is reproduced on a small scale in the minute folding and puckering seen in almost every weathered surface of the strata in question. This becomes especially pronounced and striking where the limestones are interstratified with amphibolite in thin bands. This is owing to the fact that the latter rock, offering more resistance than the limestone to the action of the weather, stands out in little ridges. This minute folding can be seen in a most striking manner in the limestone with interstratified amphibolite bands which is exposed to the south of the village of Ormsby, on the Hastings road (lots 32 38 in the townships of Wollaston and Limerick). Here examples of folding of every type can be obtained, in fragments having the dimensions of ordinary museum specimens.

Faulting. While folding is displayed by the sedimentary series everywhere throughout the area, faulting appears to be comparatively rare. A certain amount of subordinate faulting, however, may have taken place, since in an area of crystalline rocks, and one of such extreme complexity as that covered by the present report, the evidence of faulting is often extremely difficult to recognize.

There are, however, two lines along which the evidence of faulting is distinct. These both lie in the southwest corner of that area covered by the Bancroft sheet, and are approximately parallel to one another, running in a direction a little east of north.

The first of these faults passes through the Burleigh batholith near its east side. It starts from Stony lake, on lot 7, concession II of the township of Harvey, which is about two miles from the margin of the batholith, and crossing diagonally through the township of Burleigh, passes out of this township on concession XII, where it is a little over half a mile from the margin of the batholith. It then continues up along the eastern margin of the Anstruther batholith, which is, as has been explained, really continuous with the Burleigh batholith, having the gneiss of this batholith on one side and the amphibolite of the limestone series on the other. It continues in this direction as far as con-

cession VIII of the township of Anstruther, a distance of about nineteen miles. Whether it passes still farther to the north it is difficult to determine, since beyond this point the foliation of the district strikes in the same direction as the fault, but no evidence of its continuation in this direction was observed.

This fault is not one which was produced by movement which took place after the intrusion of the batholith was completed and the rocks of the area had become cold and solid. It was developed about the time of the completion of the batholith intrusion, when the granite of the batholith was so far cooled as to have completed the development of the foliation, thus producing gneissic granite, which in the latter stages of its development must have been a mass of ever increasing viscosity, and at the time of the faulting must have become nearly solid. When it had reached this stage, stresses developed in the area, which led to the production of the fault along the east side of this double batholith, similar in a way to that which cuts off the eastern side of the domed uplift of the Uinta mountains. It is not marked by any sharply defined line of fracture, but it is a line along which the foliation of the gneiss on either side suffers an abrupt change in direction. As will be seen in the townships of Harvey and Burleigh, the strike of the foliation of the batholith on the west of the fault follows a long bow-like curve, which is cut across by the almost straight line of the fault. On the east side of the fault, on the other hand, the gneiss, which is identical in character with that of the rest of the batholith, has a strike which is parallel to the fault line. The actual line of the fault is filled with coarse pegmatite, while dikes of this rock also abound along the course of the fault. The abrupt change in the direction of the strike is especially well seen at the east end of Crab lake, where the bodies of gneiss on either side of the fault strike nearly at right angles to one another. The field evidence here shows that, as above mentioned, the intrusive movement of the batholith had been practically completed, the cooling mass being nearly solid when the fault developed, and that the last portions of the unconsolidated magma were forced out into the actual plane of the fissure, as well as into smaller accessory fractures; thus forming the masses of pegmatite and the pegmatite dikes, which, as above mentioned, are very abundant along the line of fault. The fact that these bodies of pegmatite fade away into the main granite

of the intrusion is pretty conclusive evidence that the fault was formed before the granite of the batholith had become completely crystallized.

The second fault, above mentioned, starts from the contact of the rusty weathering gneiss and the limestone, on lot 37, concession III of Anstruther, and runs in a general northerly direction to the rear of concession XII of Chandos, a distance of five miles, where its continuation would carry it beneath the waters of Tallan lake. Its further extension in this direction, however, cannot be traced, since at this place it passes into a district where the foliation of the rocks coincides with the direction which its course would take. It has, therefore, been found impossible to follow it farther, more especially as the district in question is largely covered with drift. The line of this fault in the township of Chandos is marked by an abrupt change in the strike of the rocks along its course. Unlike, however, the fault just described, it runs altogether through the sedimentary series.

In connexion with certain areas of the Grenville series in the Province of Quebec, in which the bodies of crystalline limestone are often small and very highly altered, and, therefore, coarsely crystalline, doubts were at one time expressed by Selwyn and others as to the sedimentary origin of the limestones in question. Their sedimentary origin in this region, however, is established beyond all question. In the western and northern portions of the area embraced by the Bancroft sheet, where the limestones are associated with great bodies of granite or granite-gneiss, these rocks are everywhere developed as coarsely crystalline white marbles, the original dark colouring matter having been entirely driven off, or converted into scales of graphite. Passing to the southeast portion of the area, where the limestones are less highly contorted and comparatively free from granite intrusions, as has been already mentioned in speaking of the section on the Hastings road, they appear in a progressively less altered condition, becoming fine in grain, and blue or grey in colour. Suggestions of this bluish colour commence to appear on the south side of Paudash lake, in the township of Cardiff, but the bluish limestone is first seen in quantity in the township of Wollaston, towards the Hastings road, while in the southern portion of Lake and Tudor there is a great development of the typical fine-grained blue limestone, of which

the white crystalline limestone or marble is an alteration product. Curiously enough, in a few places in the townships of Methuen and Cavendish, the intense metamorphism which has overtaken the limestone where it occurs in the great belts surrounding the batholiths, converting them into white marble, has left small remnants of the unaltered blue limestone, which have escaped metamorphism, enclosed in the great belts of white marble. The survival of these remnants of the original rock affords additional proof, if any were needed, that these highly altered limestones have developed out of a fine-grained blue limestone, quite unlike them in appearance.

There is reason to believe, as will be shown, that the alteration to which these limestones have been subjected was produced by contact metamorphism, and is due to the great granite intrusions which penetrated them, rather than to any orogenic movements.

While these rocks are in almost all cases true limestones they are found to be dolomitic in some places, and occasionally pass into true dolomites. The presence of magnesia in them is, in some cases, connected with the occurrence of intrusions of basic pyroxenic rocks.

Although great developments of pure limestone are found in many parts of the area, as, for instance, about Jack lake, in the township of Methuen, and Deer lake, in the township of Cavendish, the limestone bands, as a general rule, are more or less impure, owing to the presence in them of grains of various silicates, as well as owing to the existence of numerous interstratified bands of gneissic rocks, and amphibolites of various kinds.

The gneisses which are found associated with the limestones of two classes. To the first of these belong gneisses which are really portions of the intrusive granite of the batholiths, that have penetrated the limestone series, and have become foliated by the movements which have induced this structure in other rocks of the area. These gnessies are reddish in colour, and have the characters of gneissic granite, and may either run parallel to or across the banding of the limestone. The proportion of this variety of gneiss which is present is in many cases very considerable, as, for instance, in the band on the eastern s[illegible] the Anstruther batholith in the township of Burleigh.

To the second class belong gneisses which are really integral parts of the limestone series. These evidently represent sandy

or clayey bands, often more or less calcareous, which were interstratified with the original limestones when these were deposited. One very common variety of this class is a fine-grained rusty weathering gneiss, often holding graphite, and identical in character with that found in the Grenville series everywhere in the Northern Protaxis; and some specimens of which, from the district north of Montreal, were found to contain sillimanite, and when analysed were found to have the composition of ordinary clay slate. Bands of this, and allied gneisses, are found in the limestones almost everywhere in the district embraced by this report.

In addition to these gneisses of undoubtedly sedimentary origin which occur associated with the limestones, there are in certain parts of the district great bodies of gneisses similar in appearance and character, which are found in separate occurrences without interstratified limestones, but often adjacent to limestone bands. These, together with occasional bands of quartzite, of which the most notable is that which runs diagonally across the township of Monmouth, are represented by a special colour on the map. They are well seen in the southern portion of Chandos, and in Cavendish. These gneisses present a considerable variation in character, and it is not possible in all cases to be certain of their origin. They are, however, distinguished from the gneissic granite, and there is strong reason to believe, as will be shown, that they consist of very highly altered sediments, or that they at least contain sedimentary material. Like the limestones, they are invaded and penetrated by the gneissic granites of the batholiths.

Associated with these gneisses on one hand, and with the gabbros and diorites on the other, and often passing into one or the other so that it is frequently impossible to accurately define their respective limits on the map, is another class of rocks, which have been grouped together under the general name of amphibolites. These are also found interbanded with limestones in many places. While many varieties of these rocks occur in the area, differing considerably in appearance from one another, they have as common characters a dark colour and a basic composition. Quartz, which is one of the commonest constituents in gneisses, is absent, or is present in very small amount, while hornblende and feldspar, the latter chiefly plagioclase, are the main constituents of the rock. Pyroxene, or biotite, often re-

place the hornblende in part. A pale green colour has been used on the Bancroft sheet to represent the amphibolites, which colour serves well to indicate the relation of certain varieties to the gabbro and diorite intrusions of the area, which are represented by a deeper shade of green.

Two of the most important varieties of these amphibolites are separated from the rest, and are represented by special designations on the map. One of these, which has been termed the feather amphibolite, always occurs in ain bands interstratified with limestone; and derives its name from the curious feather-like development of large skeleton individuals of hornblende, or pyroxene, which appear on the plane of the stratification of the rock, and which give to the rock a striking appearance when it is split in this direction.

The other variety of amphibolite, which also occurs frequently as heavy bands in the limestones, is of a finely granular character, without very distinct foliation, and on the weathered surface presents a uniform but minutely speckled appearance, owing to the intimate association of the minute grains of hornblende and feldspar. On this account, during the prosecution of the field work, this variety was designated as the pepper and salt amphibolite, and in the legend of the Bancroft sheet is designated as granular amphibolite.

The determination of the origin of these amphibolites has been one of the most difficult problems presented in the study of this area. It is at the same time one of the most important. As a result of the field work which has been carried out, it has been ascertained that these rocks have originated in a widely diverse manner. It can be shown that certain of them are altered igneous intrusions, as, for instance, the granular amphibolites which cut through the limestones on the shore of Jack lake, in the township of Methuen, and which have the form of undoubted dikes. Others, as the feather amphibolite, can be proved to be of sedimentary origin, representing certain harder, more or less siliceous or dolomitic bands in the original limestone. In fact, all stages in the passage from one to the other have been found. It has also been proved that elsewhere amphibolites have been produced on a large scale from the alteration of the limestones by the metamorphic action of the granite batholiths. It is found that, under intense metamorphism, a number of rock types, very differ

ent in origin and character, yield a convergent type of alteration products, which belong to the class of amphibolites, and which resemble one another so closely that they are in many cases indistinguishable.

While, however, the origin of certain occurrences of the amphibolite has been definitely determined, the rock produced by the action of metamorphism, from widely different materials, is so similar in character that, in many cases, where the mode of occurrence throws no light on the genetic problem, it is impossible to determine, with absolute certainty, the origin of particular occurrences of the rock. It is highly probable, judging from their character and mode of occurrence, that the amphibolite bands associated with large gabbro and diorite layers, as, for instance, that running in a northeasterly and southwesterly direction through the township of Wollaston, and that occurring in the southeast portion of the township of Cardiff, thence crossing Chandos into Anstruther, represent chiefly highly altered basic volcanic ashes and lava flows connected with vents represented by the gabbro stocks. The latter of these amphibolite bands presents a great variation, from place to place, in the character of the constituent rock. While some of the constituent varieties are well banded, others are streaked, or present an appearance strongly resembling a flow structure, with lighter coloured lath-like forms thickly scattered through them, and which are highly suggestive of feldspar phenocrysts; while others have an appearance suggestive of the original amygdaloidal structure. The rocks, however, are so completely recrystallized that a microscopic examination does not yield any conclusive evidence concerning their original character, but their appearance in the field in many places, for instance about Lowrie lake and on the road running south from the east end of Paudash lake, is highly suggestive of their derivation from great ash beds, by extreme metamorphism. In Cardiff and Anstruther, there is in this band a considerable admixture of reddish acid rocks, or others presenting in places a sort of eutaxitic structure. This acid element in the band may be connected with the peculiar granitic mass which crosses Pine lake, and which is described on page 127.

A similar lava-like occurrence of the more acid type is that which is coloured as amphibolite, and which forms a heavy

band in the limestones on lot 28, concession X, and lot 29, concession XI, of Cardiff.

The heavy bands, or bodies of almost massive granular amphibolites which are found interstratified with the limestones and feather amphibolites in many parts of the area, and which are typically developed on the road running between concessions XIII and XIV of Chandos, almost certainly represent intrusive sills or floors connected with the centres of eruption represented by the great dioritic intrusions in the northern part of the same township.

A small body of intrusive amphibolite is also seen on lot 28, concession I of Anstruther. This, although it is so small that it is not represented as a separate area on the map, is probably, judging from its petrographical character, genetically connected with the long narrow body of the same rock which is found on the Burleigh road in the northeast corner of the adjacent township of Burleigh. The amphibolite in question holds a considerable quantity of mica, and contains many little corrugated vein-like inclusions of pegmatite. The composite rock thus represents either a fine example of a mixed magma, or an example of an amphibolite thoroughly penetrated by an invading granite magma.

Amphibolite of a similar character to this is also found elsewhere in the district. In a scarp on the north side of the road crossing the lot above mentioned, this micaceous amphibolite is seen forming the lower portion of the cliff, while above it are exposed a series of steeply tilted strata, consisting of thin alternating bands of limestone and feather amphibolite, which stratified series is abruptly cut off by the lower micaceous amphibolite into which it dips. The relations here seem to mark the micaceous amphibolite as an intrusive mass, and its petrographical resemblance to other bodies of amphibolite in this part of the region seem to indicate that they, too, are probably of similar origin.

The development of amphibolite out of limestone by the action of the granite batholiths need not here be further referred to, as it is considered in detail in that section of the report dealing with the granites of the area, and the contact action which they exert.

It is also highly probable that much of the amphibolite so intimately associated with the limestone and the sedimentary

gneiss, represents beds of metamorphosed volcanic ashes, which will explain the very intimate relations existing between the two classes of rocks, and their frequent passage into one another. That volcanic forces were active in the district is clearly shown by a great development of orthophyres, and similar felsitic rocks, in the township of Lake.

In addition to the amphibolites which are of igneous origin, there are several great intrusions of gabbro in the area. These are distinguished from the amphibolites by their massive character, as well as by the shape of the intrusions. They are composed of a dark basic gabbro, containing a considerable amount of hornblende, which, however, is often, and probably always, of secondary origin. Of these intrusions, those crossed by the Hastings road, in the townships of Tudor, Limerick, and Dungannon, are specially worthy of mention, since they have a striking influence on the character of the district, forming blocks of very rough country, which is in striking contrast to the more level character of the surrounding districts underlain by limestones and amphibolites.

The gabbro masses which have been carefully examined, as, for instance, those crossing the Hastings road on lots 41 to 45 of the townships of Tudor and Lake, and the second occurrence on the same road, on lots 13 to 31 of the townships of Limerick and Wollaston, as well as that about Eagle lake, in the township of Wollaston, and the great mass in southeastern Glamorgan, can be seen to send out apophyses into the surrounding rocks, and to hold inclusions of the latter. A curious little mass on lots 19 to 22, concession IX of Wollaston, cuts directly across the strike of the limestone series which it penetrates.

While the gabbro masses on the Hastings road are pretty uniform in character throughout their respective areas, some of the other occurrences of gabbro show a very marked tendency to differentiation into a number of varieties. This is especially true of the small intrusion above mentioned in the township of Wollaston, and also is well seen in the large gabbro mass near the southern border of Glamorgan and Monmouth. This latter, on lot 35, concession IV of Glamorgan, develops into a body of titaniferous iron ore. A more detailed account of these differentiation products is given in the section of this report specially devoted to the consideration of the gabbros.

The gabbro intrusions, from their form and from their petrographical resemblance to the associated amphibolites, are, there

is reason to believe, the plutonic portions of ancient volcanic vents, whose explosion products, in the shape of volcanic dust and ashes, are now represented in many of the great amphibolite bands which occur so closely associated with, and often wrapped around the gabbro masses in question.

Another class of rocks which have also been represented on the map by the same green colour, are the anorthosite intrusions which occur in the townships of Burton, Dudley, Harcourt, Minden, and Dysart. These rocks, instead of being very dark in colour, are white, and resemble marble in appearance. They bear a striking resemblance to the albitic phase of the nepheline syenite, and like this are composed almost exclusively of plagioclase feldspar. This feldspar in these anorthosites, however, in all cases where it has been examined, has proved to be a basic plagioclase, usually labradorite. The rock is, therefore, an anorthosite, and not a syenite, and has consequently been classed with the gabbros. It is doubtful, however, whether genetically this anorthosite is not a phase of a nepheline syenite rather than of the gabbro magma.

One of the most interesting and important groups of rocks in the area embraced by this report is that of the nepheline and associated alkaline syenites. These are, as a rule, light in colour and coarse in grain, and generally show a more or less distinct foliation, which coincides in direction with that of the surrounding rocks. This foliation is not a secondary structure produced by the deformation of an originally massive rock, but is a primary structure developed during the solidification of the rock.

The rock in places displays an abnormal coarseness in texture, passing into nepheline syenite pegmatites, in which masses of nepheline a yard in diameter may be found. The rock also shows a great variation in the relative abundance of the constituent minerals, and thus gives rise to many varietal forms. Thus, in places, the nepheline disappears, and a pure white albite syenite results, while elsewhere the rock is made up almost exclusively of nepheline. Elsewhere, again, in the occurrences found in the northeastern portion of the area embraced by the Bancroft sheet, the magma was very rich in alumina, which separated out as corundum upon the crystallization of the rock. This corundum-bearing syenite has been made the basis of an extensive industry, being worked for corundum on a large scale at Craigmont, in the township of Raglan.

With the exception of the isolated occurrence of nepheline syenite in the township of Methuen, this rock is always found in close association with limestone, and always at, or very near the contact of the limestone with the granite of the invading batholiths. It is frequently seen in the act of eating its way into the limestones, and apparently replacing them, while it is always found to pass into the granite through an intermediate syenitic phase. The nepheline syenite is believed to represent a peripheral phase of the granite intrusions. A discussion of these genetic relations is given, together with a petrographical description of the several varieties of the rock, in a subsequent portion of this report.

In an area where the geological structure is so complicated as in that now under consideration, and where the rocks are so intensely metamorphosed and invaded by immense amounts of igneous material, it is difficult to determine the true succession and thickness of the strata, or even whether the limestones in adjacent, but separated parts of the area, correspond stratigraphically to one another. One of the most favourable places for the purpose of working out a geological succession is afforded by that part of the district where the four townships of Anstruther, Chandos, Burleigh, and Methuen meet.

A well defined synclinal fold is here seen, the axis emerging from beneath the Palæozoic strata, on concession VII of the southern portion of the township of Burleigh, and running in a direction about N. 10° E., to lot 10, concession XIII of this township; where, taking a more westerly course, it passes out of Burleigh, on lot 25, concession XIV, and resuming its original course, crosses the south-eastern corner of the township of Anstruther, entering the township of Chandos on lot 1, concession X; and on lot 3 of this concession it passes into a fault, which continues in this direction to Tallan lake. This synclinal here lies between two faults, as shown on the Bancroft sheet, and is succeeded on the east by an anticline, whose axis can be traced throughout the length of lots 38 and 39 of Anstruther, from the southern border of the township to the line between concesssions IV and V. About Duck lake, a mile and a half to the east of Tallan lake, there appears what is evidently the upper portion of a batholith, which has not been eroded sufficiently deep to expose the granite core. The waters of Duck lake occupy

the summit of the batholith, from which there is a quaquaversal dip, which to the southwest develops into the above mentioned anticline. The structure is further complicated by the presence of two masses of amphibolite, probably both of intrusive origin, in the southeast corner of Anstruther. These folds expose the succession of strata, given in descending order in the table below. This table does not include the limestone and granular amphibolites which occur to the southwest of Loon lake, as the relations of these rocks, on account of their somewhat disturbed character, are not quite clear. If a line of section be taken running from lot 10, concession XIII of Burleigh, where the highest beds in this synclinal basin are exposed, to a point in lot B, on the line between concessions I and II in the southwest corner of Chandos, which may be taken as the upper limit of the rusty gneiss; and if the dip of the strata along this line be taken as 40°, which is a fair average; and if another line of section be taken commencing at the base of the feather amphibolite (which succeeds the rusty gneiss), on lot 4 of the line between concessions VIII and IX of Chandos, and crossing the strike of the rocks to the summit of the series here measured at the margin of Duck lake, taking the average dip along this section as 20°, the following thickness for the several members of the combined section is obtained:

Limestone of Jack lake...................	6,770 feet.
Rusty weathering gneiss, with associated amphibolites, crossing lots 29 to 35 of concession I of Anstruther..................	5,754 feet.
Limestone, with bands of feather amphibolite, north of Loon lake.....................	3,060 feet
Amphibolite north of Loon lake	2,190 feet.
Limestone at Duck lake (nearly flat, only surface exposed), say	50 feet.
	17,824 feet.

In making these estimates of the thickness of the strata it is assumed that the banding of the several rocks represents a survival of the original bedding. It certainly does, in the case of the limestones and feather amphibolites north of Loon lake, and probably does in the case of the other rocks in this portion of the area. It is also assumed that the rocks along the line of section are free from subordinate folds.

Another line of section, along which the Grenville-Hastings series is excellently exposed, and along which measurements with a view to determining the thickness of the series may be made, is furnished by the Hastings road. This is one of the most striking sections of strata of pre-Cambrian age to be found anywhere in the world. The road was built many years ago by the Government, for the purpose of enabling settlers to penetrate into what was then a very wild and inaccessible portion of the Dominion. Instead of building the road in question across the limestones, thus securing a comparatively level course, a line was drawn on a map, and orders were given to lay out the road along the line in question. The result was that a long road was constructed, starting from the rear line of the township of Madoc, and running in an almost straight line to the Madawaska river, holding throughout almost its entire course a direction of N. 20° W. This road, which traverses the whole width of the Bancroft sheet, and almost the whole width of the area embraced by the Haliburton sheet, fortunately for students of geology runs about at right angles to the strike of the country rock; and throughout the whole southern portion of its course traverses the Grenville series, affording excellent exposures. The selection of this course for the road was, however, correspondingly unfortunate for the settlers who took up land in the district, since the road holds its course quite irrespective of hill or valley, and passes directly across several great gabbro intrusions, which give rise to an exceedingly rough type of country, and which might easily have been avoided had a slightly different line been adopted in the construction of the road. Throughout its course, as far north as the village of Bancroft, in the township of Faraday, the Hastings road traverses the Grenville-Hastings series, but the relations and attitude of the strata which it crosses in the district which lies to the south of the southern margin of the area dealt with in this report, have not as yet been determined with sufficient accuracy to enable any measurements to be based upon it, except for a short distance immediately south of the limit of the Bancroft sheet.

Starting, however, from a point on lot 30 of the township of Madoc, three miles southeast of lot 10 on the Hastings road — a point on the southern edge of the Bancroft sheet — a continuous section is obtained going north on the Hastings road to lot 61, where the road changes its direction a little, and from thence the

section is continued to the village of Bancroft, on the line between lots 59 and 60, where the road passes between the townships of Dungannon and Faraday. Just beyond this point the Grenville series is cut off by the nepheline syenite, on the border of the great northern batholith of gneiss. The distances traversed are as follows:

From lot 30 of Madoc to lot 61 of Tudor, on the Hastings road	9·5 miles	
From lot 61 of Tudor, on the Hastings road, to lot 60 of Faraday, on the Hastings road.	23 "	
		32·5 miles
Width of Tudor gabbro intrusion as crossed by the Hastings road	2 miles	
Width of Thanet gabbro intrusion as crossed by the Hastings road.	2·4 "	
Width of Umfraville gabbro intrusion as crossed by the Hastings road	2·8 "	
		7·2 "
		25·3 miles
		133,584 feet.

As will be seen by consulting the Bancroft sheet, throughout this whole length of 25·3 miles the Hastings road passes continuously across the limestones and amphibolites of the Grenville series, and throughout this whole distance crosses these latter practically at right angles to their strike.

Furthermore, throughout the whole distance these strata dip in a southerly direction, at high angles. Here and there at long intervals, and for a few yards, a reversed or northerly dip can be observed, but this is merely local, owing to a minor undulation in the strata, and has no stratigraphical significance.

The angle of dip naturally varies somewhat from place to place, but the average dip may be taken as 45°. This is a minimum estimate, the average dip along the whole section being, in all probability, somewhat higher. Taking this value, we find the following result:

Apparent thickness of the Grenville series along the line of section	25·3 miles	133,584 feet
True thickness of the Grenville series along this line of section	17·88 miles =	94,406 feet

It is scarcely credible that the series attains this enormous thickness, but it must be noted that the series is one which, along the whole length of this section, presents a continuous alternation of beds of varying character, so that it is not a foliation, but a true bedding, that is observed and measured. It is, furthermore, to be noted that although this series may have been repeated by isoclinal folding, there is no stratigraphical evidence that such is the case, and this folding has nowhere brought up the basement upon which the series was deposited, a fact which indicates again that the series, even if so folded, is extremely thick.

It is impossible, however, to definitely determine whether the series is one which has been repeated by isoclinal folding, for there is no horizon sufficiently well marked to permit of its being recognized in a repeated series. The amphibolite bands, which at first sight might be supposed to be capable of furnishing such horizons, do not afford them, and if they represent altered pyroclastic material, their original distribution on the sea bottom would probably be very irregular, even before the series was subjected to folding.

For purposes of comparison, the estimated thicknesses of some of the other great developments of pre-Cambrian rocks in North America are here presented. These are as follows:—

Huronian—Marquette iron range, Michigan, U.S.A.[1], 12,590 feet.

Huronian—Menominee iron range, Michigan, U.S.A.[2], 4,650 to 6,400 feet.

Huronian—Penokee iron range, Michigan, U.S.A.[3], 13,950 feet.

Huronian—Mesabi iron range, Minnesota, U.S.A.[4], 6,800 to 8,800 feet.

---

[1] Van Hise, C.R., and Bayley, W. S. The Marquette Iron-bearing District of Michigan. Monograph. U.S. Geol. Survey, 1897.

[2] Bayley, W.S.—The Menominee Iron-bearing District of Michigan. Monograph.—U.S. Geol. Survey, 1904.

[3] Irving, R. S., and Van Hise, C. R.—The Penokee Iron-bearing Series of Northern Wisconsin and Michigan. Monograph.—U.S. Geol. Survey, 1892. This thickness is arrived at by adding to the aggregate thickness of 1,950 ft., given for cherty limestone, quartz slate and iron bearing member, an additional thickness of 12,000 ft. for the upper slate member, which thickness is that of the Hanbury slate, which in the Menominee range is its equivalent.

[4] Leith, C. K.—The Mesabi Iron-bearing District of Minnesota. Monograph.—U.S. Geol. Survey, 1903.

Huronian and Keewatin—Vermilion iron range, Minnesota, U.S.A.,[1] 13,350 to 15,550 feet.

Couchiching series in Rainy Lake district, Ontario, Canada,[2] 23,760 to 28,754 feet.

With these may be compared:—

Belt formation in Montana, U.S.A.,[3] 12,000 feet.

Pre-Cambrian of Lewis and Livingstone ranges, Montana, U.S.A.,[4] 9,900 to 10,700 feet.

In all these districts there is, as in the district at present under consideration, a possible error due to repetition by folding.

In the Grenville series, as has been stated, limestones predominate.

In the Burleigh-Chandos section (described on page 31) the Jack Lake limestone is essentially a body of pure limestone, while the Loon Lake limestone band may be estimated to be about half limestone. This gives a thickness of about 8,350 feet of limestone in that section, out of a total of 17,824 feet, that is to say, 46·8 per cent of pure limestone.

In the section along the line of the Hastings road, it is estimated that the blue limestone and the limestone and amphibolite, which represent the calcareous part of the series, contain about two-thirds of their thickness of pure limestone. This would give a thickness of 50,286 feet of pure limestone, out of a total thickness of 94,406 feet, equal to 53·3 per cent. This latter section, being a much longer one, probably represents more nearly the average proportion of limestone in the Grenville series as developed in this area, which in its turn affords a representative area of the series as it occurs in Canada, so that it may be stated that the Grenville series, as a whole, contains rather more than one-half its thickness of pure limestone; while, if under the designation of limestone is included, in addition to the pure limestone, the bands of gneiss and amphibolite which are interstratified with it, and which with it may be mapped as a stratigraphical unit, the proportion of limestone in the series is much greater.

[1] Clements, J. M.—The Vermillion Iron-bearing District of Minnesota. Monograph.—U.S. Geol. Survey, 1903.

[2] Lawson, A. C. Geology of the Rainy Lake Region.—Ann. Rep. Geol. Surv., Can. 1887-8, pt. F, pp. 1012-1021.

[3] Pre-Cambrian Fossiliferous Formations, Bull. Geol. Soc. Am., vol. x, pp. 201–215.

[4] Bailey Willis, Stratigraphy and Structure of Lewis and Livingstone Ranges, Montana. Bull. Geol. Soc. Am., vol. xiii, pp. 316–324.

The thickest development of limestone in any occurrence of the Huronian in America is the Randville dolomite, in the Menominee range, which attains a thickness of 1,500 feet. In the Belt formation, and in the series of pre-Cambrian rocks in the Lewis and Livingstone ranges, there is a thickness of limestone amounting to 4,400 and 5,400 feet respectively.

As will be seen, the thickness of limestone in the Grenville series is much greater than in any of these.

It may be safely stated that the Grenville series presents by far the thickest development of pre-Cambrian limestones in North America, and that it presents at the same time one of the thickest, if not the thickest series of pre-Cambrian rocks on this continent.

AREAL EXTENT OF THE GRENVILLE SERIES

Not only has the Grenville series a great thickness, but it has a great areal extent. It is exposed along the southern border of the protaxis, from the Georgian bay eastward to a point considerably beyond the St. Maurice river, which flows into the St. Lawrence at the town of Three Rivers. It extends to the northward in the Laurentian highlands at least as far as the latitude of Cobalt, although not reaching so far west as that point which lies in a Keewatin and Huronian district. To the southeast, it is stated by Professor H. P. Cushing to be exposed at intervals over the whole Adirondack area, while to the southwest, deep borings under the city of Toronto have brought up from beneath the Palæozoic, cores of a white crystalline limestone which evidently belongs to this series. This area has a superficial extent of 83,000 square miles. In areal extent, therefore, it can be compared in North America only with certain of the greatest developments of the Palæozoic limestone, as, for instance, the Knox dolomite of the southern Appalachians. Over this area of 83,000 square miles, this Grenville series is not, of course, now continuously exposed. It is penetrated in many places by great intrusions of granite and anorthosite. This is especially true of the Adirondack mountains, in which these intrusives are especially numerous. This area, however, is one which was undoubtedly covered by the Grenville series.

In all probability, however, the areal distribution of the Grenville series is much greater than this. In many parts of

the Laurentian highlands, far to the north of the limit here taken as the boundary of the Grenville series, areas of white crystalline limestone, and associated rocks, are found, which are of identical character. Enormous developments of such limestone, similar in all respects to the Grenville series, are, for instance, found about the shores of Hudson strait. Whether, however, these northern limestones belong to the same series is not at present known. Definite information on this point, however, may be obtained when our knowledge of this great northern country becomes more complete. It is furthermore very highly probable, as the Grenville series along the southern margin of the protaxis everywhere disappears to the southward beneath the Palæozoic cover, that in this direction it originally had a much greater extent than that over which it is at present exposed. The facts, however, in our possession at present show it to be one of the great limestone series of North America, and it presents the greatest development of limestones known in the pre-Cambrian.

When Sir William Logan, in the early years of the Geological Survey of Canada, made a study of the Laurentian system, as developed in the Province of Quebec, he found that this system of rocks, in that part of the Dominion, consisted of the fundamental gneiss, on which there reposed a great thickness of altered sedimentary rocks, chiefly limestone, which latter series he termed the Grenville series. Later, when he came to investigate the district north of Lake Ontario, in the eastern portion of the province of that name, he found a series of rocks similar in general petrographical character to the Grenville series, but much less highly altered. These he called the Hastings series, and he considered that they probably represented the Grenville series in a less altered condition.

The Hastings series, in Hastings county, however, was found to be associated with great masses of gabbro and diorite, and also to hold in places belts of conglomerate, which gave to it a certain petrographical resemblance to the Huronian series, which Logan had found to the south of Lake Huron and elsewhere. The presence of the great intrusions of these basic rocks, as well as the belts of conglomerate, led some of the later writers to conjecture that the Hastings series might really be the equivalent of the Huronian, rather than a less highly altered phase of the Grenville.

This, however, remained merely a matter of conjecture, for the two series were nowhere found together, so that the stratigraphical relations could not be determined. In the Hastings series, moreover, as in the Grenville series, limestones were the preponderating element; while in the true Huronian series, this rock occurred only in very subordinate amount.

In the area at present under discussion, the more altered portion of the district, embraced in the accompanying Haliburton sheet, belongs undoubtedly to the Grenville series, being petrographically identical in every respect with that series, as developed in the original area, and occupying, furthermore, the same relation to the northern gneiss as it does in this original area, which lies farther to the east along the same margin of the northern protaxis. It is equally true that the less highly altered rocks, which occupy the southeastern portion of the area covered by the present report, and whose distribution is shown in the northeastern corner of the Bancroft sheet, form the northern extension of the original area of Logan's Hastings series. The study of the area embraced by the Bancroft sheet therefore affords a key to the problem of the relation of the two series in question, so far as their development in this area is concerned. The petrographical difference between the Grenville and Hastings series is found to be one of degree of metamorphism. There is a progressive increase of metamorphism met with on going from the south of the district toward the invading batholiths and great granite areas of the north. This affects all the rocks of the area, and gradually changes the petrographical facies which characterizes the Hastings series, into that of the typical Grenville. In the southern and less highly altered portion of the area, where there is little or no granite, there are certainly more numerous intrusions of diorite, and more amphibolite; but it is doubtful whether these rocks are relatively more abundant as compared with the volume of the associated limestones than in the portion of the area which belongs to the Grenville, where both the limestones and amphibolites are torn to pieces by the granite batholiths. This metamorphism furthermore increases so gradually that it is impossible to indicate any line which could be drawn between a less and a more altered portion of the area. If there be in the area two series of rocks differing in age, these two series are not the Grenville and the Hastings series, for what has been termed the Hastings series is merely a less altered phase of the Grenville.

Furthermore, no stratigraphical evidence of unconformity, of the nature of a divergence of strike, can be found within this area of stratified rocks.

There is but a single fact which suggests that in the area under consideration two unconformable series may occur, and that is the presence at certain places of beds or bands of conglomerate, some of them, however, very limited in extent. The whole value of this line of evidence, however, depends upon the possibility of demonstrating that these rocks are true sedimentary (epiclastic) conglomerates, and not crushed (autoclastic) conglomerates, or volcanic (pyroclastic) conglomerates. Omitting a number of occurrences which are clearly and indisputably autoclastic in origin, there are seven occurrences of these conglomerates in the area which merit consideration in this connexion. These are embraced in that portion of the area covered by the Bancroft sheet.

These seven occurrences of conglomerates will be briefly considered.

(1.) *Monmouth, lot 19, concession VIII.*—This is the most westerly of the occurrences in question, being seen on the Monck road, where the road crosses this lot. The conglomerate, which is 90 feet in width, occurs at the eastern contact of the belt of nepheline syenite which here crosses the road, but it is not found elsewhere along the extended contact line of this large body of syenite. At this point the nepheline syenite is very poor in nepheline, having the character rather of the alkali syenite, and is much traversed by pegmatite dikes, which are poor in quartz, and often, in fact, free from that mineral. The limestone series is here, toward the contact with the syenite, developed as a dark, highly micaceous gneiss, often containing a little quartzite, which is immediately succeeded across the strike by a very impure banded limestone, much twisted and contorted, and having a general course N. 30 E. The matrix of the conglomerate is formed of the dark, highly micaceous gneiss above mentioned, through which are thickly disseminated sub-angular, or often well-rounded pebbles; the larger consisting of fragments of the syenite, and the smaller of separate feldspar crystals, often perfectly rounded, notwithstanding their excellent cleavage. The materials composing the pebbles are absolutely fresh, showing no trace of decomposition.

The appearance of the rock in places simulates, in a marked manner, a true conglomerate, but the rock is evidently not of epiclastic origin, for a more detailed examination of the occurrence shows that the syenite, and the pegmatite dikes above mentioned, run into the biotite gneiss in the form of apophyses, which break apart, and finally are disintegrated into grains of their constituent minerals, which become disseminated through the gneissic rock. The evidence obtained by this curious occurrence goes to show that the conglomerate did not result from sub-aerial decay, but was produced by dynamic action, which gave rise to movements along the contact of the two rocks, resulting in the tearing to pieces of the apophyses of the syenite which penetrate the gneissic rock, probably at a time when both rocks were highly heated.

(2.) *Wollaston, lot 17, concession IX.*—This is a narrow band of rock, with small pebbles of quartz and felsite, as well as a few of a dark fine-grained amphibolite, which crosses the road about the middle of this lot, and can thus be traced diagonally across the lots to a point near a second road on the southeast corner of lot 16, concession X. Immediately to the southeast of this occurrence there is found a series of thinly banded amphibolites, some of them resembling felsites, with strings of limestone, dolomite, and quartz, the whole much crushed and sharply folded. A careful examination of this occurrence strongly suggests that the pebble-bearing band is a zone where the movements, which have been developed in this area, are exceptionally pronounced, and that the pebbles are fragments of harder bands, the structure being of autoclastic origin.

(3.) *Wollaston, lot 17, concession III.*—This occurrence is met with on the road between Coehill and the Ridge post-office. It outcrops near the margin of the great limestone belt which occupies this portion of the township of Wollaston, being situated on the east side of the amphibolite band or belt which runs diagonally across the township, the occurrence above described being found on the west side of the same belt, about four miles farther north. The country rock is, therefore, limestone, interbanded or interstratified with some amphibolite. The conglomerate occurs in heavy beds, the matrix being, in some cases, composed of silicates, and in other cases of limestone. The pebbles are chiefly amphibolite of different varieties, but some of them are quartzite, or gneiss. Associated with this conglomerate are bands of amphi-

bolite, as well as a large amount of massive dioritic rock, probably of igneous origin. Some of the amphibolite bands show numerous rounded or lenticular spots of a white colour, which give to the rock an appearance suggestive of an amygdaloidal structure.

A microscopic examination was made of a number of the amphibolite pebbles, and also of the variety possessing the apparently amygdaloidal structure. It was found that these were all representative of the same rock, showing minor variations in the relative abundance of the constituent minerals and in structure. This rock is composed of hornblende, biotite, feldspar (probably all plagioclase, although it is not all twinned), and epidote, usually in small idiomorphic individuals, with a little magnetite, and in some varieties a little calcite. The feldspar has an approximately equi-dimensional development, giving the rock a pavement structure, and the hornblende is in stout needles, sheaves, and skeleton crystals. The magnetite also, in some cases, occurs in the form of fine skeleton crystals. The rock has a more or less pronounced foliated structure. In the case of the varieties possessing the pseudo-amygdaloidal structure, it was found that the amygdules were merely ocellar spaces, representing portions of the rock in which the hornblende and biotite were absent, and the feldspar constituted practically the whole rock. In these spaces an individual or two of tourmaline is found in some cases. The pebbles are flattened out, although not to such a marked extent when the matrix consists of limestone, and are rarely over a foot in diameter, but usually much smaller.

With regard to this occurrence it is to be noted that the limestone band in which it is found, as shown on the Bancroft sheet, here makes a sharp turn through almost a right angle. A careful examination of the occurrence shows clearly that some of this conglomerate is certainly of autoclastic origin, resulting from the sharp pinching and squeezing of amphibolite bands occurring in the limestone. The movements in the rock have undoubtedly been very great, some of the pebbles being 2 feet long, and only an inch or two wide. Others have certainly been squeezed apart, thus giving rise to several smaller pebble-like masses. Whether, however, the structure is entirely autoclastic it was found impossible to determine with certainty.

(4.) *Township of Tudor, lots 9 to 19, concessions XVII, XVIII, and XIX.*—Here, in the northern portion of the township

of Tudor, two small masses of granite occur in the limestone-amphibolite series. Between these there is a belt of rock more or less conglomeratic in character, the pebbles in some places being abundant, and elsewhere sparsely disseminated. The occurrence of this belt of conglomerate, in close proximity to the granite mass, suggests that possibly the granite might represent an older land area, from which the materials of the granite pebbles were derived.

This part of the area was mapped by Dr. A. E. Barlow, and the geological relations of the occurrence were worked out by him. In a paper which appeared some time since[1], referring to the more easterly of the two granite masses, he says. -

"This batholite has an irregular, though somewhat oval outline, presenting a series of bays, with occasional small arms, the former occupied by wedge-like areas of the clastic rocks. It covers the northern portions of concession XIX of Tudor, and the southern part of concession I of Limerick, extending from lot 16 in Tudor eastward and beyond lot 9. The area characterized by its presence is exceedingly rough and barren, presenting, as usual, a series of low rounded hills, with occasional precipices, and intervening swampy flats. Microscopically the composing rock is medium textured, of a distinct though pale flesh colour, weathering white where exposed to atmospheric agencies. To the unaided eye it has every appearance of an ordinary granite, and would undoubtedly be classified as such by most observers. Under the microscope, however, plagioclase is seen to be greatly preponderant, while hornblende is the most abundant ferromagnesian constituent, although biotite, altered to chlorite, is likewise present. The rock must, therefore, be placed with the diorites, although it evidently represents a rather acid type. Associated with this rock, and apparently a differentiation product of the same magma, is a massive gabbro-diorite. The coloured constituent shows the deep green borders and pale interiors characteristic of uralitic hornblende, although the alteration of the original pyroxene is quite complete. Many individuals show a tendency to assume the actinolitic habit, and areas and patches still more intimately associated with the more acid phases of the rocks are rather typical

[1] On the Origin of some Archæan Conglomerates. The Ottawa Naturalist, February, 1899. Vol. XII, pp. 205-217. Plates VI-IX.

amphibolites, the hornblende and other constituent minerals having undergone still more extensive deformation and dislocation.

The place where these supposed conglomerates were first noticed was on lot 13, concession XIX of Tudor, a short distance north of Beaver creek. At this locality some angular boulders composed of this material, and evidently carried thence from a source not far distant, were deposited from the drift-laden ice along the base of the diorite cliffs, which here form the north side of the valley of Beaver creek. A search was made, with the result of finding exactly similar strata in place, forming a small band completely enclosed in the intrusive mass and extending completely across lot 13, as well as a short distance east and west into the adjacent lots. Detailed examination revealed much more extended exposures on the hills to the northward of Gilmour station, situated chiefly on lots 11 and 12 in concession XVIII. On lot 12, concession XIX (of Tudor), an exposure of the usual crystalline limestone is seen in contact with the granitic-looking diorite. The junction between the two rocks is exceedingly irregular and jagged, and re-entering angles of the limestone fill up the interstices in the diorite. On the other hand, arms or points of diorite pierce the limestone, and their continuation outward is seen to have been broken in the stretching to which the rock has been subjected, leaving a series of rounded lumps of the intrusive rock extending out into the limestone, and entirely separated from the parent mass. In other instances, possibly a little more remote from the batholite, the limestones are often penetrated by a series of more or less parallel dikes, most of which are pegmatitic in origin and structure. The extreme deformation of these relatively much more brittle bands, or dikes, produces autoclastic rocks, which are undistinguishable in many instances from the ordinary clastic conglomerates."

Dr. Barlow's paper also contains some excellent photographs showing the development of this autoclastic conglomerate from dikes.

This occurrence was visited by the International Committee on the correlation of the pre-Cambrian rocks of the Adirondacks, the original Laurentian area, and eastern Ontario, during July, 1906. Regarding this occurrence of conglomerate, the Committee reported as follows:—

"The Committee considered these conglomerates to be in part of autoclastic origin, and, in all probability, in part of volcanic origin, representing tufaceous material derived from volcanic centres now represented by the masses of granite associated with it. Dr. Barlow, however, who mapped the occurrence, considers them to be of exclusively autoclastic origin. The time at its disposal did not enable the Committee to make a detailed examination of the stratigraphical relations of this conglomerate, but, after the field work of the Committee was brought to a close, Messrs. Cushing and Adams returned to this locality and re-examined the conglomerates. They found that they were interstratified with limestones, and consequently of the same age as these rocks, and that, on approaching the granite mass lying to the east, these rocks were thrown into a series of very sharp folds, evidently due to their being pressed against the granite mass, and that the granite mass, immediately about its contact with these rocks, exerted a very pronounced exomorphic contact action, changing the limestones, for a distance of at least 100 yards, into a mass of reddish-green rock, consisting of an admixture of epidote, garnet, pyroxene, and other minerals. The Committee, therefore, considers this conglomerate to be of interformational origin, and to have no special structural significance."[1]

The committee found that the westerly of the two granite masses sent out intrusive dikes, or apophyses, into the surrounding limestone series, and was, therefore, like the more easterly granite mass, of intrusive origin and later date.

(5.) *Township of Cardiff, lot 18, concession I.*—A fine grained granite, with an aplitic facies, has been described (p. 127) as occupying the shores of Pine lake, in southern Cardiff. Just beyond the southern extremity of Pine lake (on lot 18, concession I of Cardiff) this granite is succeeded by a series of rocks consisting of limestones interstratified with amphibolite and beds of quartz. These dip away from the granite at a high angle, and at a distance of 1,000 feet from the granite contact, measured across the strike of the sedimentary series, a bed of conglomerate, nine feet thick, appears intercalated in a band of quartzite, apparently lying conformably on the strata just described, and striking N.15°E. with an easterly dip (away from the granite) at an angle of 40°. This conglomerate is in its turn succeeded for the next 1,250 feet

[1] Journal of Geology Vol. xv, No. 3, 1907, p. 202.

across the strike by a series of well-bedded rocks, consisting chiefly of impure limestones and quartzite, like that below the conglomerate. Intercalated with these are rocks resembling highly altered lavas and beds of volcanic ash, containing at one place a bed of rock resembling arkose. Beyond this to the east, towards Paudash creek, the country becomes heavily wooded, the occasional exposures consisting of rocks similar to those above described, but with no conglomerates.

The quartzite-like rock, where it occurs associated with the conglomerate, and overlying it, shows on its weathered surface little irregular cavities suggestive of scolithus, but whose origin is doubtful. In places also the rock shows a structure strongly resembling, and which probably actually is, false bedding. The series, although, as above mentioned, well-bedded, is in many places sharply folded, the beds being abruptly twisted back upon themselves.

The pebbles of the conglomerate are in some cases round, but are usually flattened in the direction of the strike, and also elongated in the direction of the dip of the bed. With a view to ascertaining the relative abundance of the pebbles of the different varieties of rock contained in this conglomerate, the pebbles on the surface of the rock, on two large exposures at different places, were counted and classified. The results are shown in the following table:—

	First exposure Per cent	Second exposure Per cent
Fine grained pink granite	78·9	75·0
Grey quartzite	1·1	0·6
Coarser grained granite	1·0	.
Amphibolite, with scales of biotite	....	13·0
Green pyroxene rock	5·0	3·8
Limestone	18·5	7·6
	104·5	100

The fine-grained granite pebbles bear a striking resemblance to the granite occurring about the end of Pine lake, and the amphibolite is like that which is found underlying the conglomerate. The green pyroxene rock is like that developed in limestone belts in all parts of the area, by the action of granite intrusions. The pebbles of the impure limestone are represented by cavities

on the weathered surface of the conglomerate, but on breaking open the rock, portions of the undissolved limestone pebbles are found at the bottom of the cavities in question. The paste of the conglomerate is slightly calcareous.

[illegible] search for the continuation of this conglomerate was made both to the north of the occurrence in the district about Lowrie lake, and to the south, where the old Burleigh road crosses concessions XIV and XV of Chandos, on lot 7. No trace of it could be found in either direction, although in the district about Lowrie lake, h[illegible] n dolomitic and associated with a great variety of [illegible] sometimes feather amphibolite—and in other cases [illegible] marked resemblance to altered lavas and ash beds were [illegible]; these basic and apparently volcanic beds being in places [illegible]ted with reddish acid rocks, the two in some cases min[illegible] tic structure.

[illegible] conglomerate, the appearances are distinctly in favour [illegible] ng it to be of true epiclastic origin. A certain doubt concerning [illegible] origin, however, remains, in view of the fact that the area i[illegible] which there has apparently been marked volcanic activity, as well as considerable folding. Under these conditions a small isolated occurrence of pyroclastic conglomerate might easily have been produced, and there is also a possibility of the development of the rock through autoclastic agencies.

(6.) *Lake, lots 16 to 21, concessions IV, V, and VI.*—This is one of the largest developments of conglomerate in the area, consisting of a number of beds, the chief of which are shown on the Bancroft sheet. These beds are of very considerable thickness, for although their width, as shown on the Bancroft sheet, is somewhat exaggerated, the bands as represented containing interstratified material, single beds of conglomerate are found which have a width of 210 feet as exposed, although the true thickness would be considerably less, the strata having a dip here of about 50 degrees.

These conglomerate beds alternate with layers of a very fine-grained red felsite, often porphyritic, which is identical in character, and apparently continuous with that forming the great mass which lies between Cedar and Copeway lakes. This, on its northern side, fades away into the coarse-grained granite of Copeway lake, and is apparently its peripheral development. It is a volcanic rock, belonging to the aporhyolites or apotrachytes.

Interstratified with the conglomerate there are also beds of dark micaceous amphibolitic rocks, which strongly resemble the matrix of the conglomerate, as well as bands representing metamorphosed ash beds, and a few of rusty weathering gneiss, such as are common in the Grenville series associated with the limestones.

The pebbles of the conglomerate consist of a fine-grained reddish felsite, identical in character with that of the felsite masses with which it is associated, together with a few pebbles of white quartz rock. In all the occurrences these pebbles are much flattened and squeezed out into lenticular forms, and in some cases, where the rock is traversed by little contortions, the pebbles are often more or less twisted. Magnificent specimens showing these structures are yielded by the thin slabs which break off from the glaciated surfaces of the rock when these become slightly weathered. These pebbles are, as a general rule, very abundant in the rock. The groundmass, as above mentioned, consists of a dark grey amphibolitic rock, which flows around the pebbles with a distinct foliated structure, and is, as above mentioned, similar in character to certain of the interstratified bands.

No distinct evidence of autoclastic origin could be obtained in the case of this rock, although certain banded varieties of rock were observed in the vicinity, which might produce such a conglomerate under the influence of great movement. The rock, however, shows no evidence of autoclastic origin over many large exposures. It might, however, have been produced by the crushing of piles of interstratified volcanic agglomerate.

Among the conglomerates met with in the southeast portion of lot 18 of concession IV, there is one band 15 feet in width, in which the pebbles are in most cases well rounded, and in which, while some of them consist of the reddish felsite which constitutes the pebbles of most of the conglomerates of this district, there are also numerous pebbles of granular white quartz rock, probably vein quartz, and some of the magnetite-actinolite rock similar to that found in association with the iron ore about 200 yards farther west, near the shore of Whetstone lake. This occurrence is referred to in some detail in the section dealing with economic geology in connexion with the description of the iron ore on this lot.

(7.) *Methuen, lots 2, 3, and 7, concession I.* This occurrence consists of two beds of conglomerate, which are found within a

quarter of a mile of one another. They are interstratified with the same series of rocks, and both disappear beneath the Silurian outlier north of Vansickle post-office. The most southerly of these bands is one of the largest which occurs in the area embraced by the Bancroft sheet, having a width of 750 feet as exposed across the strike, which represents a true thickness of 550 feet, the dip of the bed being at an angle of 40 degrees. This conglomerate lies between two beds of limestone, and is on the strike of the conglomerate just described from the central portion of the township of Lake, although it is about five and a half miles distant. These two occurrences are not, however, continuous, but each of them thins out on the strike, having a lenticular form. In this Methuen occurrence practically all the pebbles are of the same character, consisting of the same very fine-grained quartz orthoclase rock (felsite) which preponderates in the pebbles of the conglomerates in Lake, although occasionally very small pebbles of white quartz rock are also seen. These pebbles are all much squeezed out, having the form of elongated flattened cakes, so that the rock in small exposures does not display its conglomeratic character, but presents a thinly banded appearance. Under the microscope the pebbles are seen to be composed of a microcrystalline aggregate of quartz and orthoclase, showing only faint indications of parallelism, while the matrix of the rock consists of microcline and biotite, the latter being quite abundant, and occurring in the form of little scales arranged in parallel position, giving to the matrix a strongly marked foliation.

The second band of conglomerate is precisely similar in appearance to that just described, but is much thinner, and occurs interstratified in the series of amphibolites and banded felsitic rocks of this district. In it the pebbles are very abundant, and are flattened into the form of thin discs.

The conclusion is, therefore, reached, that the first four occurrences of the conglomerate just described may be considered as autoclastic, or pyroclastic, in origin. With regard to the last three occurrences, this is much less certain. The conglomerate in Cardiff (No. 5) certainly looks as if it marked the base of an overlying, unconformable series. It is, however, a comparatively thin bed, and it has, moreover, been found to be impossible to trace it either to the north or to the south of the point in question. It is, of course, recognized in this connexion that one occurrence

of conglomerate found, far outweighs the absence of conglomerate in many places where it might be looked for, as establishing an unconformity. If, however, the evidence of unconformability at this one point be regarded as certain, the unconformability in question exists between two series of rocks identical in petrographical character, and presenting such a uniformity both in character and structure that any attempt to delimit the two series on the map, except at the point in question, would be purely arbitrary, and based on mere conjecture. The other two occurrences, in Lake and Methuen (Nos. 6 and 7), evidently belong together, succeeding one another as they do on the strike. Here the evidence of such thick beds of conglomerate would seem to indicate the existence of a break in the structural succession. In these conglomerates the pebbles are almost without exception felsite, similar to the felsite and orthophyre masses with which they are associated. These latter, however, are apparently intrusive in the series with which the conglomerate is interstratified. This might easily be the case if the conglomerates represented bodies of volcanic ejectamenta and ashes, developed in connexion with the eruption of the orthophyres. It is doubtful, however, whether this is so, especially in the case of the conglomerate band near Whetstone lake.

Under the circumstances, therefore, the whole development of sedimentary rocks in the area has been mapped as one continuous series, although it is possible that two series, identical in petrographical character, and closely enfolded, exist. Whether this be so or not, it may be possible to determine, when the adjacent area to the south of the eastern part of the Bancroft sheet is critically studied, since the strike of these conglomerates carries them over into the area in question, and the conditions for study there may prove to be more favourable.

The geological history of the area may be briefly summed up as follows:

The district was in pre-Cambrian times covered by a sea, in which there was deposited an immense series of sediments aggregating many thousand feet in thickness. The thickness of the series shows that the period of deposition was a long one, and the prevailing calcareous character of the sediments shows that it was probably of marine origin. That there was land, however, in the vicinity, is shown by the fact that a certain amount of

argillaceous and arenaceous sediment found its way into this sea. It was deposited at a time of violent volcanic activity, for there is reason to believe that a large part of the great volume of amphibolite interstratified with the normal sedimentary material represents volcanic ashes and other clastic material of volcanic origin, which was from time to time thrown out into the sea in which normal sedimentation was going forward. There are also flows of porphyritic lava, and bosses of plutonic rocks, probably representing the deeper parts of volcanic centres.

Concerning the nature of the basement upon which this immense accumulation of sedimentary material was laid down we have no certain knowledge, for no part of it can be recognized at the present time as the original floor.

This great series was then folded in a general direction N. 30° E., and probably contemporaneously with the folding, was invaded by an enormous body of granite. This granite slowly rose in the form of great batholiths into the overlying series, disintegrating it and becoming filled with countless fragments of the invaded rock. In the case of the limestones this granite not only disrupted them, but changed them into amphibolite. The amphibolite produced in this way, as well as that referred to above as occurring interstratified with the limestones, and of different origin, was in many places dissolved by, or incorporated into, the substance of the granite, taking the form of basic streaks or *schlieren*.

While in the southeast corner of the area the sedimentary cover is thick, and almost continuous, on going toward the northwest it becomes, as the result of more intense erosion, progressively thinner, while the volume of granite breaking up through it gradually becomes greater until the northern limit of the Bancroft sheet is reached, where the sedimentary series is fretted away, and is represented only by occasional shreds and patches of amphibolite scattered through the batholiths of gneiss, and arranged in lines conforming to the strike of the foliation of the latter. The erosion to the north has thus cut down into and laid bare a deeper part of the section, where all the rocks, both invaded and invading, everywhere show indisputable evidence of great movement while in a soft or plastic condition.

Here are displayed the roots of the mountains. From what has been said it will be seen that there are presented in this great

area precisely the same phenomena as those seen elsewhere in North America, and the evidence available seems to indicate that this statement may be extended to all parts of the world. Where the oldest stratified, or stratiform formations are exposed, these rest upon great bodies of granite, usually gneissic in structure, which penetrate them in great batholithic masses, the contact being an intrusive one. Thus the Keewatin, which, in the region of the great lakes, on the border of the Canadian shield, is the oldest series, and which, although containing a large amount of volcanic material, abounds also in ordinary sedimentary deposits in many districts, rests upon granite which is intruded through it. Farther to the east, all along the border of the same shield or protaxis in Ontario and Quebec, as well as in the Adirondack mountains, the Grenville which forms the base of the sedimentary series, shows precisely the same relations.

THE GRANITES AND GRANITE-GNEISSES, WITH THEIR INCLUSIONS AND CONTACT PHENOMENA.

Out of a total area of about 4,200 square miles in the district covered by the present report, granites and granite-gneisses occupy 2,596 square miles, or nearly 62 per cent of the whole. The principal development of these rocks is in the northern portion of the area which is occupied almost exclusively by them. In the southwestern portion large batholithic areas of the granite, as has been mentioned, appear rising through the overlying sedimentary series; while smaller areas of the same rocks occur as intrusions in the southeastern portion of the area. These rocks have for the most part a distinct foliation, although certain of the smaller areas (as for instance that about Lake Copeway, in the central portion of the township of Lake) are quite massive. In the larger areas, however, the foliated structure in many places gives way to a granitoid one, and every stage of the transition from one to the other can be clearly seen. The smaller batholithic areas of gneissic granite in the southern portion of the area are identical in composition and character with the great northern area, and are evidently portions of it, separated by areas of the overlying sedimentary strata which have sunk down between the batholiths, and have thus been preserved from erosion. The surface character of the country underlain by these southern granite masses is also identical with that underlain by the great northern gneisses.

The great areas underlain by this rock, although, speaking generally, very uniform in the character of the rock exposures, do not consist of a granite, or granite-gneiss of perfectly uniform character throughout, but are composed of granites, or granite-gneisses, through which are distributed, in varying amount, inclusions of amphibolite, dark in colour and basic in character. The origin of these inclusions, and their relation to the granite, will be discussed later. Of the granite rocks which form the chief part of these great areas there are two varieties, which may be designated as the red gneiss and the grey gneiss. The same three rocks are described by Cushing as making up the corresponding body of gneiss in the Adirondacks region of the State of New York.[1] Of these the red gneiss is by far the most abundant.

The granite-gneiss area thus consists of:—

1. Red gneiss.
2. Grey gneiss.
3. The amphibolite inclusions.

These will be considered in succession.

I. RED GNEISS.

The red gneiss is the prevailing type in all the gneissic areas. It is a rock which is medium to rather fine in grain, and light in colour, weathering to a pale reddish or pink. It is composed almost entirely of feldspar and quartz, the former preponderating. Some biotite is also invariably present, but this is very subordinate in amount. As will be mentioned later, the rock generally shows signs of cataclastic structure. When examined under the microscope, small amounts of hornblende are sometimes found in the case of the southern batholiths; and in the gneiss from one or two localities a little muscovite is associated with the biotite. As accessory constituents, iron ore, apatite, and zircon are usually present, in very small amount, and in a few localities a very small amount of garnet also occurs in the rock. When examined in polarized light a proportion of feldspar is often found to present a fine cross-hatched twinning, characteristic of microcline; while most of the other feldspar grains, as a general rule, show no twinning; a small proportion of the feldspar usually shows the simple albite twinning characteristic of plagioclase. Upon a

[1] 19th Ann. Rep., State Geol. of N.Y., p. 149.

microscopic examination, therefore, the rock would seem to be essentially a quartz orthoclase rock in which the orthoclase is frequently replaced wholly or in part by microcline, or, in some few cases, by microperthite. When, however, separations of the constituents of the rock are made by means of a heavy solution, it is found that the amount of lime soda feldspar present is much greater than would be supposed from a study of the rock sections. In fact a large amount of a lime soda feldspar, having the specific gravity of oligoclase, is found to be invariably present, and frequently it preponderates over the orthoclase. In making these separations Thoulet's solution was employed, and after the removal of the dark constituents of the rock the fluid was gradually diluted until a specific gravity slightly under 2·65 was reached, at which point the quartz fell. On further dilution the oligoclase, having a specific gravity of between 2·623 and 2·644, was thrown down, and in no case was there a noticeable amount of any heavier feldspar present. From the fluid, when still further diluted, first the albite (if any were present) fell, and then the orthoclase and microcline were separated. In order to ascertain whether this unexpectedly large proportion of oligoclase was a common characteristic of the gneisses of the area, eleven specimens of the typical red gneiss, from widely separated points, were selected, and separations of their constituents were made, with a view to determining the character and approximate proportions of the feldspars present, with the following results:

Township of Airy, lot 3, concession IV. Typical fine-grained distinctly foliated red gneiss, taken from the large exposures on the banks of Hay creek, where it enters Long lake. Oligoclase and orthoclase were found to be present in about equal amounts, while the amount of quartz was found to be about equal to the total content of feldspar in the rock.

Township of Sherbourne, lot 26, concession III. A medium-grained typical red gneiss, which in the field is seen to pass into a coarse-grained and more massive pegmatitic facies. Two feldspars — oligoclase and orthoclase — are present, the former being rather smaller in amount than the latter. Quartz is rather less abundant than the oligoclase. As usual, the dark constituents are present only in very subordinate amount.

Township of Livingstone, lot 10, concession V. —A fine-grained reddish gneiss, showing in places coarser strings. Under the

microscope it is seen to be composed essentially of feldspar and quartz, with only a small amount of biotite. Untwinned feldspars, apparently orthoclase and microcline, are present in large amount, and the proportion of feldspar grains, showing the ordinary albite twinning, is small. A little iron ore, and a very few minute individuals of apatite and zircon, complete the list of constituents present. A separation of the constituents of the rock by means of Thoulet's solution showed, however, that the amount of oligoclase present was considerably greater than that of the orthoclase and microcline taken together. An analysis of this rock, which may be taken as typical of the great body of red gneiss throughout the area embraced by the report, was made by Prof. Nevil N. Evans, of McGill University. The results of this analysis are as follows:—

SiO_2	76·99 per cent.
Al_2O_3	12·45
Fe_2O_3	1·03
FeO	0·49
MnO	tr.
CaO	0·98
MgO	0·21
K_2O	4·29
Na_2O	3·46
CO_2	none
H_2O	0.26
Total	100·16

When from this analysis the relative proportion of the constituent minerals is calculated, the results obtained by the separation of the constituents are substantiated. If, after calculating the atomic proportions of the rock, the lime is united with sufficient alumina and silica to make anorthite, and from the potash and soda in the same way the proportions of orthoclase and albite respectively present are calculated, it will be found that the amount of alumina remaining is almost exactly that which is required with the excess of the other constituents to make biotite, excepting a small amount of ferrous and ferric oxides, which remain over in the proportion in which these oxides are present

in magnetite. The results of the calculation carried out in this way are as follows:—

Orthoclase	25·58	per cent.
Albite	29·34	"
Anorthite	5·00	"
Quartz	37·68	"
Biotite	0·90	"
Magnetite	1·39	"
Water	0·26	"
	100·15	per cent.

It will thus be seen that the amount of anorthite present is sufficient when united with the albite to give 34·34 per cent of an acid oligoclase, having the formula $Ab_6\ An_1$ thus bearing out the results obtained by the Thoulet separation; and which, as compared with the orthoclase, is present in about the proportion of 3 to 2.

When the calculations are made to ascertain the position which this rock would occupy in the quantitative system of classification recently proposed by Messrs. Cross, Iddings, Pirsson, and Washington, the rock is found to occupy the following position:

Class I—Persalane.
Order 3—Columbare.
Rang 2—Alsbachase.
Sub-rang 3—Tehamose.

Township of Peck, shore of Smoke lake.—The specimen was taken from large exposures of a gneiss made up almost exclusively of feldspar and quartz, the dark constituents being represented by a few flakes of biotite. Both oligoclase and orthoclase were found to be present, and in the proportion of about 1 to 5.

Township of Lutterworth, lot 19, concession XI.—The typical flesh-red gneiss, composed of quartz, microcline, plagioclase, and an untwinned feldspar, apparently orthoclase, with a small proportion of biotite, muscovite, magnetite, sphene, apatite, and zircon, were present as accessory constituents. A separation by means of Thoulet's solution showed that the plagioclase feldspar present had the specific gravity of oligoclase, and that it

was very nearly equal in amount to that of the orthoclase and microcline taken together.

Township of Glamorgan, lot 9, concession IX.—This is a specimen of the typical red gneiss occurring on the road between Maxwells crossing and Bark lake, in the Glamorgan batholith. A separation of the constituents made by Mr. L. C. Gratton, B.Sc., of McGill University, shows that oligoclase is present in large amount, probably exceeding in quantity the amount of orthoclase present in the rock.

Township of Monmouth, lot 14, concession II.—A very pale pink gneiss from near the northern limit of the Anstruther batholith. Quartz and oligoclase are present in about equal amount. The potash feldspar is subordinate, there being about two and a half times as much oligoclase as potash feldspar present in the rock.

Township of Wollaston, lot 27, concession IX.—A typical, coarse-grained, well foliated granite-gneiss from the southern extremity of the granitic area occurring in the northwestern portion of the township of Wollaston. In this rock the oligoclase was found to exceed the potash feldspar in amount.

Township of Wollaston, lot 19, concession XIV.—This specimen was taken from the northern end of the same Wollaston mass. A separation proved that a large amount of oligoclase was present, but that it was exceeded in amount by the potash feldspar.

Township of Methuen, lot 15, concession V.—A distinctly foliated typical gneiss from the north shore of Connors bay, an arm of Lake Kasshabog. It is typical of much of the gneiss of the Methuen batholith. A large amount of oligoclase is present.

Township of Methuen, lot 17, concession V.—This specimen represents the finer grained variety of the gneiss from the shore of Bottle lake, and belongs to the same Methuen batholith as that just referred to. Under the microscope it is seen to consist of microcline and plagioclase, with small amounts of quartz, and of an untwinned feldspar. The iron-magnesia constituents are biotite and hornblende, which are present in about equal amounts, but both of which are very subordinate constituents. An analysis of this rock, made by Mr. M. F. Connor, B. Sc., gave the following results:—

SiO_2	73·33	per cent.
TiO_2	0·17	"
Al_2O_3	13·55	"
Fe_2O_3	0·58	"
FeO	1·53	"
MnO	0·04	"
CaO	1·66	"
MgO	0·45	"
K_2O	3·12	"
Na_2O	5·01	"
H_2O	0·45	"
	99·89	per cent.

It is impossible in the case of this analysis to calculate the exact proportions of the iron-magnesia constituents which are present, owing to the fact that the exact composition of both of these minerals is unknown. The norm, however, is given below. By this is meant the calculation of the analysis into the form of certain standard minerals, being the mineralogical composition of a rock into which such a magma might crystallize under slightly different conditions.[1] The norm presents in this case very nearly the true percentage of the various minerals present, but a certain proportion of diopside and hypersthene are calculated, which are represented by other combinations in the actual rock. The norm is as follows:—

Orthoclase	18·35	per cent.
Albite	42·44	"
Anorthite	5·28	"
Quartz	27·72	"
Diopside	2·57	"
Hypersthene	1·92	"
Magnetite	0·93	"
Ilmenite	0·30	"
	99·51	per cent.

[1] A Quantitative Classification of Igneous Rocks, by Cross, Iddings, Pirsson, and Washington, University of Chicago Press, 1903, p. 147.

The position of the rock in the quantitative classification, which may be referred to as the C. I. P. W. classification, taking the initial letters of the authors' names, is as follows:—

Class I.—Persalane.
Order 4.—Britannare.
Rang 2.—Toscanase.
Sub-rang 4.—Lassenose.

It will be seen from the results which have just been stated, that the granites, and granite-gneisses, from all parts of this region are rich in oligoclase, this mineral being present, not as the subordinate constituent, but, as a general rule, largely exceeding the amount of potash feldspar present in the rock. These rocks might thus be properly referred to as oligoclase gneisses rather than orthoclase gneisses.

This same preponderance of oligoclase was found to continue in the gneisses which underlie the district beyond the northern limit of the area treated of in this report, in the district forming the southern portion of the Algonquin Park of the Province of Ontario, as shown by an examination of a series of gneisses from this region, made by Mr. H. Hayden Sands, of McGill University.

It would be a matter of interest to determine whether a high content of oligoclase is not much more common in acid granites than is generally supposed. In examining a series of analyses of such granites from various localities it will be found that in many of them the content in soda equals or exceeds that in potash, while the percentage of lime is low, not exceeding at most 2 per cent, thus showing that they are quite different in composition from the monzonites or granodiorites. It seems probable that the plagioclase which occurs in these rocks, and which is commonly stated to be albite, is really oligoclase, as in the case of the granite-gneisses described above.

An interesting contribution to this question has recently been made by Polenow,[1] who finding that the Russian granites seemed to be rich in plagioclase, selected ten typical granites from various parts of European and Asiatic Russia, and determined accurately in each case, by microscopic measurements, the quantitative mineralogical composition of the rock. The results were as follows:—

[1] Zur Frage der Orthoklasplagioklas Gesteine. (Trans. Soc. Natur. d. St. Petersbourg. 31 Sitzsings prot. 107-111. 1900.)

Orthoclase	25·20 per cent to	35·80 per cent.
Plagioclase.	24·00 per cent to	46·13 per cent.
Quartz	10·13 per cent to	32·80 per cent
Iron-magnesia constituents.	6·40 per cent to	16·80 per cent.

In the case of these Russian rocks, however, it is possible that, although referred to by Polenow as typical granites, they may really lie between granites and quartz-diorites, belonging to one or other member of these classes of the feldspathic granolites,[1] and thus be distinct from the true granites described in this report. Only chemical analyses can decide their exact position, and these are not given in Polenow's paper.

One peculiar fact noted in connexion with the feldspar of the red gneiss is that its reddish colour can, in many cases at least, be entirely destroyed by ignition at a comparatively low temperature, showing that it is not due to the presence of oxide of iron. As a rule, in these gneisses the microcline has the least colour, the orthoclase coming next, while the oligoclase has a comparatively deep tinge. This same fact is noted by Ries[2] in the case of the red feldspar from Bedford, Ont., which is shipped to the United States for the manufacture of pottery, the feldspar in question, although red, being shown by analysis to contain little or no iron. It furthermore becomes white when calcined.

2. GREY GNEISS.

This rock varies somewhat more in character than the red gneiss, being sometimes pale reddish grey, and at other times pale grey to deep grey in colour, showing corresponding variations in composition. The differences in colour are due in part to the relative proportions of the iron-magnesia constituents, and in part to the fact that a large proportion, if not all of the feldspar present, is white or grey in colour. The rock usually weathers more easily than the red gneiss with which it is associated; and it can frequently be observed, where the grey gneiss occurs in bands in the red gneiss on the rocky shores of the northern lakes, that it shows a tendency to weather away more readily, leaving depressions in

[1] Turner, H. W. The Nomenclature of the Feldspathic Granolites. Jour. of Geol., vol. viii, No. 2, 1900.

[2] Mineral Resources of the United States. The Production of Flint and Feldspar. U.S. Geol. Survey 1901.

the face of the rock. Like the red gneiss with which it is commonly associated it occasionally takes on a massive development, as for instance on the line between lots 8 and 9, concession I of the township of Burleigh, where it occurs forming high cliffs along the shore of Stoplog lake. It usually, however, has a distinct foliation.

Specimens of this grey gneiss from six typical occurrences have been microscopically examined. The results are as follows:

Township of Nightingale, lot 23, concession VIII.—A well-foliated, rather coarse-grained variety, with a few little bands of red gneiss running through it, parallel to the foliation. Under the microscope it is found to consist chiefly of microcline and quartz There is an untwinned feldspar, apparently orthoclase, also present in considerable amount, but scarcely any feldspar having ordinary albite twinning. The iron-magnesia constituents are represented by biotite and green hornblende, both present in subordinate amount. These, together with a few grains of iron ore, zircon, and apatite, complete the list of constituent minerals. While it is possible that an analysis of the rock, or a separation of the constituent minerals, would show that some of the untwinned feldspar is plagioclase, the chief difference between this rock and the ordinary red gneiss seems to consist in the proportionally larger amount of the iron-magnesia constituents, and in the presence of hornblende among the latter.

Township of Nightingale, lot 26, on the line between concessions VII and VIII.—This is a grey, distinctly foliated gneiss, which weathers to a reddish grey colour, and contains in places darker streaks, probably due to a greater abundance locally of the iron-magnesia constituents of the rock. It is well exposed in a cutting on the line of the Grand Trunk railway. It is the prevailing gneiss over large areas in this district. Under the microscope the chief constituent is seen to be a feldspar, which is usually untwinned, but which in some cases develops the fine cross-hatched twinning of microcline, and elsewhere shows the spotted character indicative of an intergrowth with some other feldspar. There is also a feldspar present showing the ordinary plagioclase twinning. Separation of the constituents of this rock, by means of a heavy solution, shows, however, that orthoclase, albite, and oligoclase are present in approximately equal proportions, and that the rock contains no feldspar more basic

in character. The rock is rather poor in quartz, while the dark constituents are also quite subordinate in amount, and consist chiefly of pyroxenes. Two varieties of pyroxene are present, one rhombic and the other monoclinic, both light in colour, but the former, which is faintly pleochroic, is seen to be partially altered to a fibrous mineral, having the characteristics of a hornblende. A small amount of green hornblende is also present as an original constituent, as well as a small quantity of biotite, and a little titanic iron ore, partially altered to leucoxene.

This rock differs from the red gneiss chiefly in the character of the bisilicates present. On the weathered surface it is seen to hold occasional augen of feldspar, and, as shown by the microscope, it possesses a marked cataclastic structure.

Township of Livingstone, lot 32, concession VI.—This occurs associated with the red gneiss in thin bands, by the shore of Rock lake. It is composed of orthoclase and plagioclase, the relative proportions remaining doubtful in the absence of a separation, together with quartz, and a considerable amount of biotite. There are also in the rock, minute grains of chlorite associated with calcite, which evidently result from the decomposition of some mineral, probably a rhombic pyroxene, which has now entirely disappeared. This was less abundant than the biotite.

This grey gneiss differs from the associated red gneiss in the greater abundance of biotite, and in the presence of the rhombic pyroxene.

These three occurrences have been selected from the great northern expanse of granite-gneiss, represented in the Haliburton sheet accompanying this report. The following two occurrences lie farther south, the first in the Haliburton batholith, and the second in the Glamorgan batholith.

Township of Dysart, lot 24, on the line between concessions IX and X.—This rock, which is well exposed on the road traversing the lot, is representative of the grey gneiss of this district. Under the microscope it is found to consist essentially of plagioclase, quartz, biotite, and hornblende. The plagioclase is the most abundant constituent, but the quartz is also present in large amount. The hornblende is green, and occurs in irregular-shaped, more or less elongated grains, some of the larger individuals having a sort of poikilitic structure, enclosing rounded grains of feldspar. A small amount of magnetite, as well as a few grains of apatite and zircon, are also present.

Township of Glamorgan, line between lots 25 and 26, concession VIII.—This is rather finer in grain than the last rock, and has a reddish grey colour. It consists essentially of quartz, microcline, orthoclase, plagioclase, and biotite. The quartz is present in large amount, as are also the microcline and plagioclase. The untwinned feldspar above referred to as orthoclase is less abundant. Magnetite, apatite, and zircon are present as accessory constituents, in very small amounts. This differs from the red gneiss chiefly in the greater proportion of biotite present.

Township of Burleigh, line between lots 8 and 9, concession I. This gneiss, which is representative of the Anstruther batholith, resembles that last described, in that it is fine in grain, and reddish grey in colour. It is composed of orthoclase, plagioclase, and quartz, with the subordinate biotite, some grains of hornblende, and a small amount of iron ore. It differs from the red gneiss with which it is associated, in that it contains a greater proportion of iron-magnesia constituents, less quartz, and an untwinned feldspar, here referred to as orthoclase, instead of the microcline.

As the result of these examinations it may be said that the grey gneiss differs in mineralogical composition from the red gneiss, since in some cases it holds a greater proportion of iron-magnesia constituents, combined occasionally with a smaller content of quartz; and in others with a larger content of plagioclase.

3. THE AMPHIBOLITE INCLUSIONS.

Of the inclusions which occur so abundantly in the granite-gneiss, those consisting of amphibolite are by far the most common. The chief types of amphibolite, occurring as stratified, stratiform, or foliated masses associated with the limestones, or gabbros, in the southern portion of the area, are described in other portion of this report. The amphibolites occurring as inclusions in the gneiss usually represent the more massive and granular varieties of these rocks. The feather amphibolites have not so far been found as inclusions in the granite-gneiss of any part of the area.

The rock constituting these inclusions is always dark, often nearly black in colour, and usually fine in grain, heavy, and generally much more massive than the gneiss with which it is associated. In large masses of irregular shape, as a general rule no

foliation can be detected, but when the amphibolite is in the form of long and narrow inclusions a foliation can be observed, which is in most cases quite distinct. Occasionally a few streaks, somewhat coarser in grain, or either lighter or darker in colour than the main body of the inclusion, are seen running in the direction of its foliation, giving rise to a sort of flow structure. This, however, is unusual.

The foliation of these amphibolites, where it exists, coincides in direction with that of the enclosing gneiss, except when, as is often the case, amphibolite bands, after having had a foliation induced in them, are by further movements separated into fragments, which are carried along in the gneiss with a rolling movement, the foliation of the gneiss sweeping around the ends of the broken masses.

When examined in thin sections under the microscope, these amphibolites, from various parts of the gneissic areas, are seen to be tolerably uniform in character.

Smoke lake, township of Peck, concession VI. An occurrence on the west shore of Smoke lake, in concession VI township of Peck, may be taken as representing a large proportion of these amphibolite inclusions. Here the shore of the lake is formed of large exposures of a well-foliated red orthoclase gneiss, very poor in iron-magnesia constituents, and holding occasional little remnants (augen) of orthoclase, showing that it is a granulated form of pegmatite, or coarse-grained granite. In this there are a number of discontinuous bands or elongated masses of amphibolite, from 6 inches to 5 feet in thickness, varying in width, and in some cases pinching out completely when followed for a short distance along the strike. The foliation of the gneiss follows the curves of the amphibolite mass.

The amphibolite is in some places massive, and in others shows a faint foliation. It has a fine and even grain. When examined in thin sections under the microscope, it is seen to consist of hornblende, augite, a rhombic pyroxene, and plagioclase, with a small amount of iron ore, a few grains of pyrite, and a trifling amount of calcite. The hornblende, which makes up over fifty per cent of the entire rock, is of a green colour, and strongly pleochroic, as follows: $\mathfrak{a}$ pale yellow; $\mathfrak{b}$ deep green; $\mathfrak{c}$ yellowish green.

The monoclinic and the rhombic pyroxenes, in ordinary light, both being pale greenish in colour and showing the same cleavages, cannot be distinguished from one another, and taken together they are subordinate in amount to both the hornblende and the plagioclase. When the sections are examined in polarized light, however, the two minerals can be readily distinguished. The monoclinic augite is non-pleochroic, and has a strong double refraction, with the usual high extinction. The rhombic pyroxene — probably hypersthene — has a much lower double refraction, a parallel extinction, and a marked pleochroism, in pale green, reddish, and yellowish tints, the light vibrating parallel to the vertical axis being pale green. Both pyroxenes show the characters which they usually present in rocks of this class. They are generally quite fresh, although in places the hypersthene is slightly decomposed. Little irregular spots of hornblende are occasionally seen in the pyroxenes, but there is no distinct evidence of the passage of one into the other. The plagioclase is usually well-twinned, often showing the pericline, as well as the albite twinning, but there is also a considerable amount of untwinned feldspar present. In order to ascertain whether this was orthoclase, or merely some untwinned plagioclase, a separation of the constituents of the rock was made by means of Thoulet's solution, and it was found that no orthoclase was present, the feldspar being entirely labradorite, and having a specific gravity of between 2·655 and 2·69. The rock contains no quartz. The iron ore is black and opaque, being a magnetite, possibly holding some titanium. The calcite, which is present in small amount, is a decomposition product.

The rock was analysed by Mr. M. F. Connor, with the following result:

SiO_2	45·46	per cent
TiO_2	2·10	"
Al_2O_3	16·10	"
Fe_2O_3	3·12	"
Cr_2O_3	0·04	"
FeO	8·63	"
MnO	0·14	"
CaO	10·80	"
BaO	trace	
MgO	7·30	"
K_2O	0·70	"
Na_2O	2·71	"
P_2O_5	0·21	"
CO_2	1·13	"
S	0·17	"
H_2O	1·32	"
	100·23	per cent.

If the norm be calculated from the analysis, this rock will be found to have the following position in the quantitative classification:—

Class III -Salfemane.
Order 5 Gallare.
Rang 4 Auvergnase.
Sub-rang 3 –Auvergnose.

The rock is a hornblende auvergnose.

The structure of the rock is allotriomorphic. None of the constituents have even an approximately good crystalline form, and none of them show any distinct evidences of having been submitted to pressure. A clearer idea of the structure of the rock may be obtained from an examination of the microphotograph of the amphibolite next described (Plate IV). The structure which the more massive varieties of this rock possess strongly resembles that seen in the pyroxene granulites, or trap granulites, of Saxony.

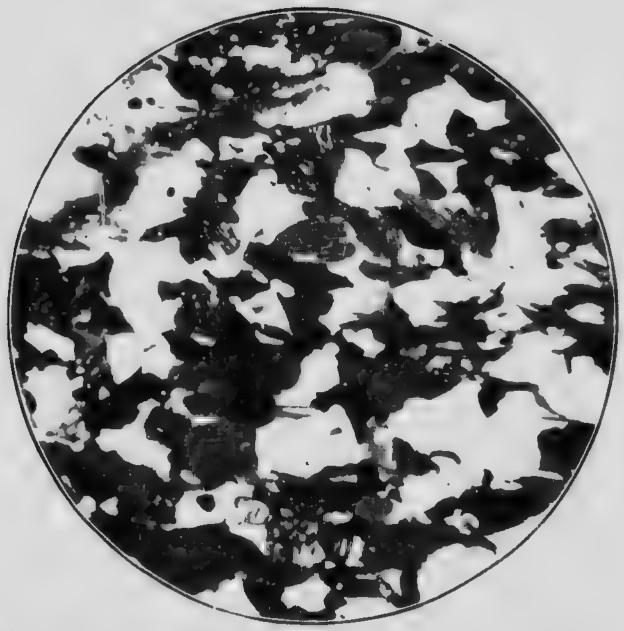
Long lake, township of Nightingale, lot 26, line between concessions VII and VIII. A lens-shaped mass of amphibolite, 50 feet long and 4 feet thick, enclosed in a reddish grey gneiss, and exposed in a cutting on the Grand Trunk railway. When examined under the microscope it is found that the iron-magnesia constituents present are hornblende, hypersthene, and biotite; the hornblende, which is as usual in these rocks green in colour, preponderating largely. The hypersthene, which is present in considerable amount, is partially altered to a fibrous green mineral, apparently also a hornblende. The feldspar constitutes about one-half the rock. A considerable proportion of this is untwinned, but as before, on making a separation of the rock constituents it is found to be entirely plagioclase, although somewhat more acid than that usually found in these rocks, having a specific gravity of between 2·65 and 2·69, and thus standing about on the line between andesine and labradorite. Iron ore is present, in not inconsiderable amount, as an accessory constituent. The structure is, as in the amphibolite just described, allotriomorphic, and there is a somewhat indistinct foliated structure. A microphotograph of a thin section of this rock is shown in Plate IV.

Amphibolites from a number of other localities have been examined microscopically. From among those, the following may be referred to briefly. As will be seen, they are in all cases practically identical with the rocks described above.

Rock lake, township of Livingstone, lot 27, concession V. This is a typical rock basin, eroded in solid gneiss, and affording on its rocky shores and islands an excellent opportunity of studying the amphibolite inclusions, which occur here as long streak-like masses, usually very sharply twisted and folded. The rock was found to be composed of hornblende, rhombic pyroxene, and plagioclase, with a few grains of iron ore, and pyrite, all the minerals having the same characters as those above described. Here also there was a certain amount of untwinned feldspar present. A separation, however, showed that all the feldspar was a basic labradorite, having a specific gravity of between 2·690 and 2·694. The associated gneiss is composed of orthoclase and quartz, with a very small amount of biotite and plagioclase.

Round lake, township of Livingstone, lot 10, concession V. A band of amphibolite 2 feet in thickness, occurring in strati-

PLATE IV



Microphotograph of granular amphibolite (inclusion in granite-gneiss) lot 26 line between concessions VII and VIII, Nightingale township

form red gneiss, excellently exposed in a high cliff on the shore of Round lake. It consists essentially of hornblende and feldspar. The accessory constituents are biotite, sphene, apatite, iron ore, and pyrite, all occurring in minute grains or scales, and in very small amount. No pyroxene is present. The hornblende is of the usual green pleochroic variety, and makes up about two-thirds of the rock. The feldspar is colourless, and for the most part shows no trace of twinning. A separation, however, shows that it has a specific gravity of over 2·651, and consequently is labradorite, or an even more basic member of the plagioclase series. There is, however, also present a much smaller quantity of another plagioclase, having a specific gravity of between 2·62 and 2·65, and which is, therefore, either oligoclase, or andesine. This, however, does not constitute more than 12 per cent of the whole feldspathic content of the rock. Under the microscope the feldspar grains sometimes show a difference of orientation in their inner and outer portions, which indicates an intergrowth of the two varieties of feldspar in question. No orthoclase, or any other feldspar more acid than oligoclase, occurs in the rock. The rock possesses a distinctly foliated structure, but no evidence of strain is visible in the constituents under the microscope.

In the same great exposure there are several much thinner bands of amphibolite, which appear to have resulted from the squeezing out of what were once thicker bands. As has been observed in many other parts of the area in similar cases when the amphibolite bands become thin, biotite replaces the hornblende to a great extent, their more micaceous character resulting in a much more pronounced foliation. In this particular case the thin bands also contain a very considerable amount of epidote, in large separate individuals, associated with the hornblende and biotite, which mineral is not found in the larger bodies.

Clear Lake township of Clyde, lot 29, concession XI. About one-half the rock consists of green hornblende. There are also a few flakes of biotite present. About one-half the feldspar is untwinned.

Rainy lake, township of Sabine, line between lots 9 and 10, concession VII.—Consists of hornblende, augite, and plagioclase, with very small amounts of biotite, iron ore, pyrite, and apatite. The augite often contains little spots of hornblende, suggesting a possible alteration of the former into the latter mineral. About

one-half the feldspar grains are untwinned, but on making a separation of the constituents it was again found that no orthoclase is present, all the feldspar being labradorite, having a specific gravity of somewhat over 2·689.

Harry lake, township of Lawrence, lot 31, concession V.—An amphibolite mass, 6 feet thick, in quartzose orthoclase biotite gneiss. It consists of hornblende, augite, and plagioclase, with a small quantity of biotite, iron ore, and pyrite. A few large grains of quartz are seen in the slide, but these probably belong to minute strings of the enclosing gneiss, which penetrate the rock.

The amphibolite inclusions above described have all been selected from localities in the great area of the northern gneiss. Similar inclusions, however, are common in the areas of this rock found in the southern portion of the sheet. Two of these have been examined by Mr. L. C. Gratton, B.Sc., of McGill University. Of these the first was an inclusion in the gneiss of the Haliburton batholith:

Township of Dysart, lot 24, line between concessions IX and X. A very dark, fine-grained amphibolite, possessing foliated structure, but showing no banding. It consists essentially of hornblende, and plagioclase, the former mineral constituting about 60 per cent of the rock. As accessory constituents there are biotite, quartz, magnetite, pyrite, apatite, and zircon, all occurring in small amount. The feldspar is in part labradorite, and in part andesine.

The second inclusion examined by Mr. Gratton was from the gneiss of the Glamorgan batholith:

Township of Glamorgan, lot 8, concession IX. This is somewhat lighter in colour, and appears to have been more or less penetrated by the granitic material of the enclosing rock. It was found to consist approximately of hornblende, 32·4 per cent; oligoclase, 40·5 per cent; quartz, 20·7 per cent; and microcline, 6·4 per cent. A little sphene, titanic iron ore, and apatite are present as accessory constituents.

In view of the question of the origin of these amphibolites, the occurrence of certain other very basic rocks in the gneisses, in intimate association with the amphibolites, is of importance. On the shore of Smoke lake, in concession IV of the township of Peck, for instance, there are large exposures of a rock, which

in the field looks like a variety of the amphibolite. It is massive and well jointed, and although its contact with the gneiss is not seen on either side, seems to form a band, possibly a dike, running with the strike of the gneiss, and at least 100 feet wide. It is situated by the shore of the same lake, and only a short distance from the first occurrence of amphibolite described above. When examined under the microscope the rock is seen to be a peridotite. It is fine in grain, and shows a faintly foliated structure, due to a tendency among the minerals to arrange themselves in lines running in one direction. It is composed of olivine, augite, a rhombic pyroxene, hornblende, with a small amount of a plagioclase feldspar, a little spinel, and a few grains of pyrite. The olivine, which is present in very large amount, is almost colourless, and is in places altered to serpentine. The augite is also nearly colourless, although portions of the larger individuals are often filled with an immense number of minute inclusions, giving them a brownish colour. The rhombic pyroxene resembles the augite, but has a parallel extinction, a lower double refraction, and in some cases shows a faint pleochroism in reddish and greenish tints. The hornblende, unlike that in the amphibolites, is brown in colour, and is highly pleochroic. These minerals make up the great mass of the rock. Of the other constituents, the feldspar occurs chiefly in granular aggregates, usually elongated in form, with a low double refraction, and occasionally showing polysynthetic twinning. The spinel is deep green in colour, and transparent, and occurs running through the rock in little strings.

Another occurrence of a rock which is almost identical with that just described, is from the shore of the same lake, in concession VI, a short distance to the south of the amphibolite described on page 63. It contains, however, no spinel, and the hornblende is paler brown in colour, in places passing into greenish brown, thus suggesting an approach to the green hornblende found in all the amphibolites. A little biotite is also present. Similar peridotites are found at other localities in the district, but do not require special description.

These rocks are identical with the amphibolites in their mode of occurrence, and in the small amount of feldspar which they contain. The pyroxene is also in separate rounded individuals, as in the pyroxene amphibolite. Again, there is a great mass of basic pyroxenite, composed almost exclusively of a pale green

augite, well jointed and without any foliation, occurring intimately associated with amphibolite on one of the large islands in Hollow lake, in the township of Livingstone (see however, page 92, where it is shown that this bears a strong resemblance to certain highly altered limestones). On lot 14, concession VI of McClintock, a mass of peridotite is found also intimately associated with amphibolite.

Again, on the shore of Burnt lake, on lot 27, concession XI of Nightingale, there occurs in the gneiss a great mass of rock which has the appearance of a gabbro. It is massive toward the middle, but becomes foliated toward the sides, and there is little doubt, from its general character and mode of occurrence, that it is a more massive development of the amphibolite commonly found in the gneisses, and described above. Under the microscope it is seen to have the character of a gabbro, with a very marked development of the zonal or corona structure so often seen in these rocks. There are a few large individuals of augite, and pseudomorphs of serpentine, the latter representing original olivines, surrounded by zones of much smaller grains of light coloured rhombic pyroxenes, mixed, especially toward the outer part of the zone, with grains of brown hornblende, and a few minute flakes of biotite. About and between these aggregates is plagioclase, well-twinned, and holding a great many rounded grains of garnet, and in some places swarms of minute pear-shaped inclusions of a green isotropic mineral, probably spinel. A small amount of iron ore, pyrite and apatite is also present. Similar occurrences are found in many places on the hills to the east of the village of Whitney, in the township of Airy, where the rock is often coarse in grain, and shows in places a species of ophitic structure suggestive of an altered diabasic gabbro. This structure, however, is obliterated by the foliation in most cases.

It will thus be seen that these inclusions, which are so widespread in the granite-gneiss areas, consist of basic rocks, which, so far as their composition is concerned, are allied to the gabbros and diabases, in some cases becoming still more basic, and finding their equivalent in the peridotites, and at other times becoming rather more acid, and having the composition of diorite.

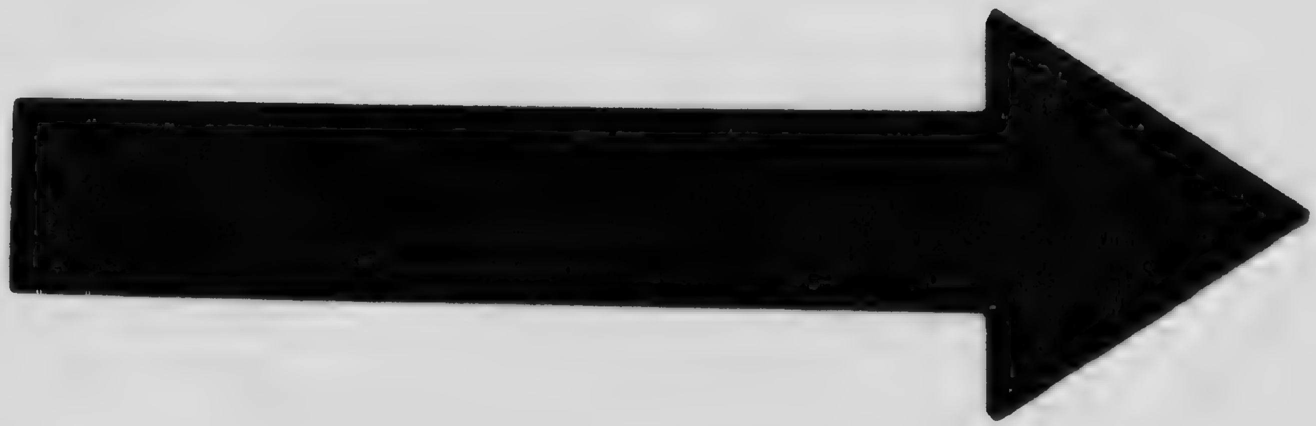
It will furthermore be seen from the descriptions which have been given above, that the amphibolite inclusions usually bear a very strong resemblance to certain of the amphibolites which

occur associated with the lime-stones or gabbros in the southern portions of the area. Those from lot 10, concession V of Livingstone, and from lots 12 and 13, concession XIV of Livingstone, for instance, resemble very closely the fine-grained amphibolite from Duck lake, in the township of Chandos.

DISTRIBUTION AND RELATIVE ABUNDANCE OF THE THREE VARIETIES OF ROCK WHICH MAKE UP THE GRANITE AREAS.

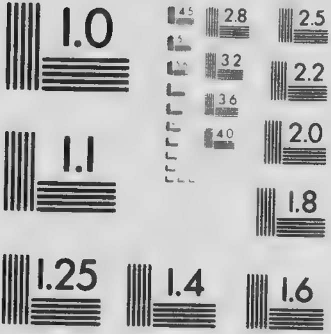
As has been mentioned, the red gneiss is by far the most abundant rock in granite and granite-gneiss areas in this region. The proportion of grey gneiss and amphibolite present, however, varies greatly in different places. In the great northern gneiss district, which constitutes over one-half of the whole area covered by the report, the red gneiss is seldom found pure and free from inclusions over any very considerable tract of country. There are few of the large glaciated exposures, seen on the shores of the numerous lakes which are found all through that part of Ontario, in which at least an occasional amphibolite inclusion is not seen. In the townships of Livingstone, Lawrence, and Nightingale, perhaps the red gneiss contains fewer inclusions, and is associated with less grey gneiss than in any other part of this northern country. But the grey gneiss and the amphibolite seem to be more abundant to the south of the line of townships above mentioned, as the district underlain by the sedimentary strata of the southeastern portion of the sheet is approached. The grey gneiss is especially abundant in the townships of Sherbourne, Guildford, Harburn, and Dudley, and is also found intimately associated with the red gneiss, across the whole country from the township of Herschel northeast to Brudenell.

In the batholiths, and smaller areas of granite-gneiss, rising through the sedimentary covering above mentioned, in the southern and more especially in the southeastern portion of the area, the proportion of grey gneiss and amphibolite also varies greatly. In the Haliburton batholith the grey gneiss and amphibolite are more abundant than they are in the northern district. In some portions of the Glamorgan batholith, amphibolite inclusions abound while in other portions of it they are entirely absent. It is estimated that on the southern margin of this batholith, on the road between Maxwells crossing and Bark lake, the amphibolite inclusions constitute about one-half of the whole



MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No 2



mass. On the Buckhorn road, which cuts across the eastern extremity of this batholith, as will be seen on consulting the Bancroft sheet, there is a considerable body of the batholith in which there are no inclusions. In the triple batholith, which runs across the Haliburton sheet from Anstruther to Cardiff, the same variation is found. The most northerly of these three batholiths breaks its way into a mass of sedimentary gneiss, through which the granite sends arms in every direction, and which is manifestly floating on an extension of the batholith immediately below it. There is thus no sharp line between the granite, with inclusions of the surrounding sedimentary gneiss, and the body of the sedimentary gneiss through which the apophyses of granite swarm. In the case of the most southerly of these batholiths, which may be termed the Anstruther batholith, amphibolite inclusions, often of very large dimensions, are found throughout the whole mass, and can be well studied in the Burleigh lakes. These inclusions, however, become extremely abundant in two portions of the batholith, namely, in the district about Eagle lake, and along the eastern margin of the batholith in the southern part of the township of Burleigh. In both of these occurrences the inclusions, as will be noted later, are not all amphibolite, but consist, especially in the former case, of the rock through which the batholith here breaks. In the eastern marginal strip of the batholith in Burleigh, the inclusions, as in the Bark Lake district, constitute about one-half the mass.

Another area where inclusions of amphibolite are very abundant in the red gneiss, is on the western side of concession IX, township of Anson, where they constitute about one-third of the whole mass. Grey gneiss is not common in these southern batholiths, except in the Haliburton one, but is seen in the townships of Snowdon, Minden, and Lutterworth.

In the Salvation granite area, in the northwestern part of the township of Wollaston, amphibolite inclusions are very rare, and grey gneiss is absent. In the Methuen batholith also they are not abundant, except along one line, which follows the east and west arms of the southern portion of Kasshabog lake, where they abound.

As granite areas containing very few amphibolite inclusions, and no grey gneiss, the following may be mentioned. That about Copeway lake in the central portion of the township of Lake,

which is an area of uniform red granite, rather coarse in grain, but showing no tendency to foliation. Under the microscope, however, the quartz in this rock shows a very uneven extinction, indicating that the rock has been submitted to pressure. The small intrusion crossed by the Buckhorn road, on concession XVII of Cavendish, and that at the west end of Contau lake on concession IV of Glamorgan, the former occurrence being massive and the latter showing distinct foliation. The Wessemakoon area of granite-gneiss also, which occupies the extreme southeastern margin of the Haliburton sheet and extends far beyond it to the east, holds very few amphibolite inclusions, although these are more abundant toward the western contact of the mass.

Any attempt to express in figures the relative proportions of the three elements which make up the granite-gneiss complex, averaging up all the areas embraced in the map, can be little more than conjecture. Venturing on the conjecture, however, the opinion may be expressed that the red gneiss probably constitutes about 80 per cent of the whole, while the other 20 per cent is divided about equally between the grey gneiss and the amphibolite inclusions.

As will be seen on consulting the maps which accompany this report, those portions of the areas in which amphibolite inclusions are especially abundant, are indicated by the presence of green dots printed over the dashes indicating the course of the foliation, while in the Haliburton sheet, where the scale is small, and less detail is shown, this distinction is not made. In neither map is any attempt made to represent the grey gneiss separately, as this would be scarcely possible; in both, this rock has been included with the red gneiss in the general designation of granite-gneiss.

RELATION OF THE AMPHIBOLITE INCLUSIONS TO THE ENCLOSING GNEISSES.

The granite-gneiss, throughout the area, with its included amphibolites and grey gneisses (with a few unimportant exceptions) shows conclusive evidence of having been subjected to movements of a most pronounced and far-reaching character. The immediate source of these movements was in the granite itself, and was due to its welling up in the form of the great

batholithic masses, whose character and distribution have been already described. The precise character of these movements, and the condition of the granite when they took place, will be considered later. It is to these movements that the prevailing foliation or schistosity of the rock is due, and they account for the fact that in only a few places does the rock possess the absolutely massive character which is found in normal granite.

When the movements, as is generally the case, have been extensive, and the granite, as it usually does, varies somewhat in grain from place to place, the rock takes on very frequently a very marked stratiform appearance, each component variety of the mass, no matter what its form or dimensions originally, being pulled or squeezed into flat, lenticular, or band like forms. These various masses, resembling beds, are usually sharply bounded and well defined against one another, but are, of course, when examined in large exposures, found to lack that continuity which obtains in true bedded rocks. They are in reality cakes or lenses, sometimes of large dimensions, but in other cases only a few feet or even a few inches in length, which thin out and disappear along both the dip and strike, when followed to any considerable distance. This bedded appearance in a body of gneiss is well shown in Plate VIII.

When grey gneiss, or especially when amphibolite inclusions are present in the prevailing red gneiss, the result of these movements is much more striking, for the dark colour of the amphibolites offers a striking contrast to the light tints seen in the weathered surface of the gneiss, and the outline of the inclusions is very clearly marked. The amphibolite, furthermore, being much more basic, is more readily attacked by the disintegrating forces of the atmosphere, and usually weathers out, giving rise to shallow depressions on exposed surfaces.

The amphibolite inclusions are of all sizes and shapes from great masses covering acres in extent, to small fragments a few square inches in area. They are, in some cases, of approximately equal dimensions, while in other cases they present narrow, ribbon-like forms. They have, in some cases, acted as comparatively rigid masses, around and about which the gneiss has flowed, carrying them along in its current, like logs in a stream; but in other cases the masses seem to have been somewhat softened, and drawn out into all manner of fantastic forms by the movements

of the enclosing rock. It is possible that these amphibolite inclusions could accommodate themselves to very slow, but not to more rapid movements when very hot, becoming more brittle on cooling; or again, they may have been plastic during recrystallization, but more brittle subsequent to it. The amphibolite is seen, however, in almost every case, to be distinctly less plastic than the gneiss, under the conditions which obtained during the movement of the rocks. Little wedge-like tongues of the gneiss can be seen forcing themselves into masses of the amphibolite, thus cutting off portions, which float away in the moving gneiss. These tongues often increase in number and size until the whole amphibolite body is divided up into small pieces, which are separated and carried away, the original mass being thus resolved into a swarm of small, sharply angular fragments. All stages of the process can thus be readily observed whereby an immense solid mass of black amphibolite, absolutely free from any granitic admixture, is resolved into a swarm of amphibolite fragments, distributed in a long stream through a body of gneiss, the individual fragments often retaining their shape so perfectly that their relative positions in the original mass can be clearly made out. There is also a marked tendency in the amphibolite masses possessing a distinct foliation, to split most readily in the direction of the foliation, the fragments thus detaching themselves from the parent mass moving off in the gneiss, in the form of flat, slab-like pieces, arranged with their longer axes in the direction of the flow. There is no part of the area in which this process of disintegration can be more distinctly seen than on the rocky shores of the numerous lakes in the township of Sherbourne.

While the detached masses of amphibolite often preserve their angular form, as above mentioned, they sometimes seem to have been softened and rendered more or less plastic, and when this is the case, the movements of the gneiss draw them out into the long and narrow ribbon-like forms referred to above. A striking instance of this may be seen on the shores of Gun lake, in concession VI of the township of Sherbourne, where there is an enormous development of the amphibolite, very dark in colour, and usually nearly massive, occupying great stretches of the shore. The gneiss can be seen running into these masses in arms, tearing

off fragments, which, when they become separated, are often stretched out, curved, and twisted as if they had been softened and rendered plastic. These, when pulled out very thin, seem to pass into ill defined grey streaks in the gneiss.

In Fig. A a sketch is given of a number of the amphibolite inclusions, which have been drawn out into lens-shaped forms in the red gneiss near the shore of Otter lake, in the township of McClintock.

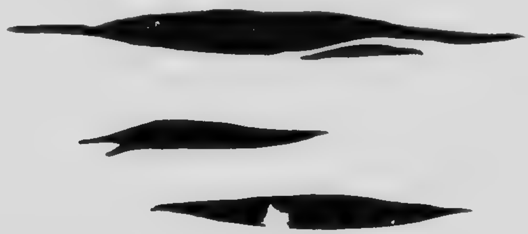


Fig. A. Red gneiss with amphibolite inclusions drawn out into lens-shaped forms, shore of Otter lake, township of McClintock. The cut represents an exposure 8 feet in length.

In many cases, after the amphibolite inclusion has been drawn out into long narrow forms, such as that represented above, it can be seen under further movement to have been torn into two or more pieces, which float apart in the gneiss, but can be clearly seen from the outline of the broken edges to have at one time formed part of the same mass (see Fig. B). It is a noteworthy

Fig. B. Elongated amphibolite inclusions pulled apart by further movement in the red gneiss. Township of Brassard, Que.

fact that when a mass is pulled apart in this way, and the resulting fragments are commencing to separate, the red gneiss, which first fills up the space between them, is always coarse in grain and of a pegmatitic facies; when the masses become further separated, the intervening gneiss, which flows in, presents the usual character, and has a foliation parallel to that of the surrounding rock.

Fig. 1. Gneiss penetrating large mass of amphibolite and cutting it in two. Eagle lake, township of Anstruther, lot 13, concession V.

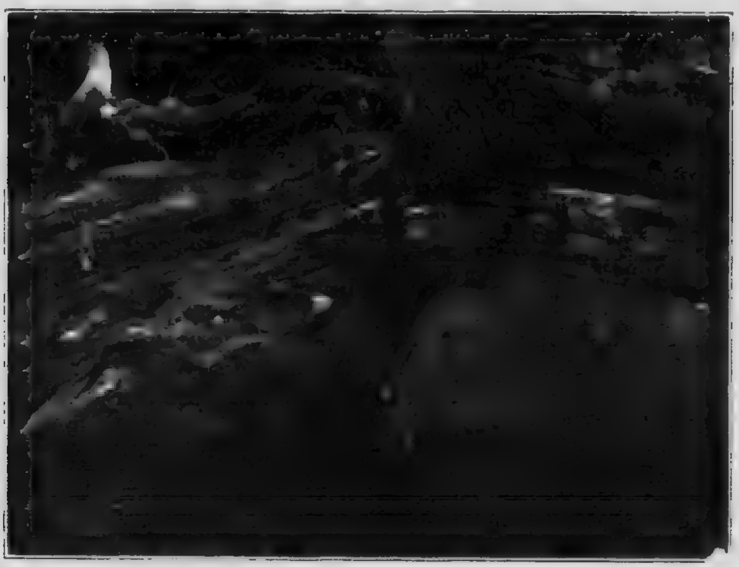


Fig. 2. Gneiss penetrating an amphibolite mass. Near south end of Crab lake, township of Sherbourne.

A body of amphibolite more thoroughly penetrated by granitic material. Shows the tendency of the amphibolite to separate into slab-like masses retaining sharp and well defined boundaries against the granite. Carlow road, quarter of a mile south of Combermere.

Plate VII

Stratiform gneiss with a few lenses and layers of amphibolite. This represents the complete [illegible]gration of a dike of amphibolite, [illegible] by extensive movements in the mass. New Mexico.

Gneiss, with large numbers of amphibolite inclusions, now represented by dark layers, [illegible] having given rise to a very well marked banded structure. Near Killaloe Station, Grand Trunk railway, township of Hagarty, Ont.

Fig. 1. Amphibolite inclusions in gneiss. Near Egan Estate railway station, township of Murchison, Ont., Grand Trunk railway.

Fig. 2. Conglomerate gneiss. Produced by intense motion in a mass of amphibolite penetrated by strings of pegmatite. The surface shown in the photograph is 4 feet wide. Fishtail lake, township of Harcourt, lot 15, concession IX.

PLATE X

Exposure of gneiss and amphibolite sharply folded in a direction at right angles to the original strike. Half a mile south of Moore falls, township of Lutterworth, Ont.

Exposure of gneiss and amphibolite sharply folded and cut by a foliated pegmatite dike. Half a mile south of Moore falls, township of Lutterworth, Ont.

As a result of these movements there develops, from a mass of granite filled with amphibolite inclusions, a more or less regularly banded rock, consisting of alternate layers of reddish gneiss and dark amphibolite.

These successive stages are illustrated by the accompanying photographs (see plates V, VI, VII, and VIII).

A remarkable amphibolite inclusion, showing the fantastic forms often assumed, is seen on the line of the Grand Trunk railway (mile post 135), near Egan Estate station, in the township of Murchison (Plate IX, Fig. 1). This inclusion has been formed on the very axis of a sharp bend in the gneiss, and has bee nearly split in two by a tongue of gneiss which has penetrated it. Its banded character has been preserved, and evidence of a certain amount of plasticity is presented, in that it is pulled out into a thin string at one end, without fracture.

A well banded rock, such as that shown in Plate VIII, can often be observed to have been sharply squeezed or folded back upon itself by still later movements. This process will, if continued sufficiently far, give rise to a banding in an entirely new direction. A good example of this is shown in Plate X, where the new direction in which the banding is being developed namely, parallel to the head of the hammer is at right angles to that which the rock formerly possessed.

Plate XI, which is a photograph taken from another part of the same exposure, shows a portion of a sharp fold which has been cut across by a pegmatite dike. This dike cut the rock after the secondary banding had commenced to be developed, but before the movements had ceased, as seen by the fact that, although it traverses the banding of the gneiss, it has itself a foliation induced in it parallel to the direction of the secondary banding, which is in course of development in the mass in the direction of the axis of the fold, i.e. in the direction of the head of the hammer.

This rock flow bears a striking resemblance to the movements seen in glacial ice, as shown, for instance, in the series of photographs illustrating Prof. Chamberlain's paper on the Glaciers of Greenland[1]. The viscosity of the moving material in one case was certainly much greater than in the other, but so also was the pressure. The resulting forms in both cases are identical.

[1] Glacial studies in Greenland. Jour. of Geol. 1896, p. 769, and 1897, p. 227.

It can readily be seen by a study of a series of these remarkable occurrences, that, as a general rule, the amphibolite is less plastic under these movements than the enclosing red gneiss. There is, however, another phase in the destruction of the amphibolite, which may be observed in many places, and which seems to mark extreme motion, combined with more than the usual degree of plasticity on the part of this latter rock. This is seen where amphibolite masses have been penetrated by immense numbers of anastomosing strings of coarse-grained granite, or pegmatitic granite, and the whole mass has then been squeezed out. A dark micaceous rock results, with lumps and crystal fragments of orthoclase, and pieces of quartz, often large in size, scattered through it. In the softer basic mass the orthoclase and quartz fragments escape destruction, and are arranged in long lines and strings. The rock resembles a conglomerate at first sight; being, in fact, a sort of conglomerate gneiss, although entirely different in origin from a conglomerate of the usual type. Its origin can be traced with absolute certainty through all its stages, on great cliff faces and glaciated rock surfaces in a dozen different places.

This development, as has been said, seems to mark extreme motion coupled with an unusual plasticity on the part of the amphibolite, and in cases where the original amphibolite mass has been completely softened, the rock may have moved for miles, still preserving intact the orthoclase and quartz fragments which represent the disintegrated remains of the originally continuous pegmatite strings. An excellent instance of the development of this peculiar rock occurs in the cliffs which border the shore of Fishtail lake, in the township of Harcourt, and is shown in plate IX, fig. 2. The photograph from which the illustration is taken represents a surface 4 feet in length, on the basset edges of a large exposure of the gneiss.

STRUCTURE OF THE RED GNEISS AS INDICATING THE NATURE OF THE MOVEMENTS DESCRIBED, AND THE CONDITION OF THE ROCK WHEN THE MOVEMENTS IN QUESTION TOOK PLACE.

It may be said, making a rough estimate, that 80 per cent of the whole gneissic complex in this district consists of the red gneiss. This presents a number of minor variations in structure.

but its general character is everywhere the same. The nature and origin of the various structures which it displays are perhaps most clearly revealed by a study of the occurrences in that portion of the area embraced by the Bancroft sheet; as for instance in the great development in the townships of Burleigh, Anstruther, and eastern Cavendish; that in Monmouth, Cardiff, Methuen, and Lake; or that in southern Chandos.

In its simplest development it is medium, or even rather fine in grain, but contains an immense number of coarser grained patches, large or small, and of irregular shape, scattered through it. It is usually cut by coarse-grained pegmatite dikes, which in composition are identical with similar textured portions of the rock itself. When the rock is massive or nearly so, these coarser portions form irregular patches (Germ-"flammen"[1]). When, however, the rock is more or less distinctly foliated they assume the form of streaks, the rock thus passing into a gneiss, made up of finer and coarser bands or streaks, which at the same time are identical in composition. The coarser flammen are indistinctly marked off from the finer portions, and the structure, as a whole, is especially well displayed on large glaciated surfaces. The rapid variation in size of grain, in this district, characteristic of the granite masses as a whole, is the same as that which is everywhere found in pegmatite dikes. This granite, like the ordinary pegmatite dike, is poor in iron-magnesia constituents, consisting almost entirely of quartz and feldspar. In some cases the granite contains porphyritic crystals of feldspar, which, when foliated, take the form of an augen gneiss. The development of the foliation referred to above is, without the slightest doubt, due to movements of some kind in the rock. That such movements have taken place is made evident by the relationship which the gneiss bears to the inclusions of amphibolite as already described, and from a study of the great sweeping curves which the strike of the gneiss follows, as shown on the accompanying maps, also from the study of every cliff, or large exposure, as well as of nearly every hand specimen of the gneiss itself. These movements have, moreover, left their mark, in the most pronounced manner, on even the minute structure of the rock.

[1] Lehmann Johannes: Untersuchungen uber die Enstehung der altkrystalinischen Schiefergesteine, p. 24 et seq.

The progress in the development of the foliated structure, as a result of these movements, can be readily followed on weathered surfaces; and still more distinctly when thin sections of the rock are examined under the microscope. These movements have affected the feldspar and quartz very differently. The feldspar phenocrysts of the porphyritic granite, or the large individuals of the pegmatitic variety, are first seen to become twisted, often in a striking manner, as shown by the curved cleavage surfaces in the hand specimens, or by the uneven extinction when examined between crossed nicols. They can then be seen to gradually break down by peripheral granulation, the granulated material so produced being forced away from the feldspar remnants in all directions. The feldspar individual at this stage, when seen in thin sections under the microscope, appears with a trail of little broken grains of feldspar running out from it on either side, in the plane of the foliation; or the large individual will break up into two or more smaller ones, which will each be granulated separately. As this process continues the large central feldspar individual becomes progressively smaller, and finally disappears, being replaced by a flat, lense-shaped mass of small feldspar grains, appearing as a streak, or lenticular patch on the surface of the rock.

The individuals of quartz, on the other hand, become flattened out into progressively thinner leaves, which run through the mass of granulated feldspar, curving around any larger feldspar remnants, and looking, on the surfaces of the rock broken parallel to the foliation, as if the mineral had been spread upon the surface of the granulated orthoclase, like streaks of butter on a slice of bread. These quartz leaves, in sections parallel to the foliation of the rock, appear, when examined under the microscope, as plates of irregular shape, with uneven extremities. In sections transverse to the foliation they appear long and narrow, sometimes forking at the extremity, and generally, between crossed nicols, seem to be divided transversely into two or more areas, which differ slightly in extinction. An interesting fact in this connexion is that in the great majority of cases the direction of extinction makes an angle of between 25 and 30 degrees with the longer axes of the quartz leaf.

The mica, or other dark constituent, if any be present in the original rock, arranges itself in the form of little dashes or streaks parallel to the general foliation.

When the process is complete all the feldspar remnants have disappeared, and a rock which may be described as a leaf gneiss results, consisting of finely granulated feldspar, with leaves of quartz and a very few biotite dashes.

A noteworthy fact is that when the granulation, as above described, is complete, and all the eyes of feldspar have disappeared, it is difficult to obtain any conclusive evidence that the rock has been submitted to pressure. Under the microscope the granulated feldspar shows no abnormal signs of pressure, and while the quartz leaves, if large, are certain to show twisting, yet if small in size they may be perfectly flattened out and show no signs of dynamic action. If the original granite, moreover, was of the normal or rather fine-grained type, the feldspar individuals, not being sufficiently large to give rise to well marked augen, break up at once into a few smaller grains, while the small quartz individuals flatten out, and the massive rock thus passes directly into a foliated one. The fact, however, that such masses of fine-grained foliated gneiss, almost invariably throughout the whole district, where large weathered surfaces are examined, show more or less abundantly surviving remnants of the large feldspar individuals, or occur intimately associated with and pass into varieties showing the augen gneiss structure, and which are certainly granulated pegmatites or porphyritic granites, establishes beyond a doubt that the gneisses in question are nothing more than completely foliated developments of a rock which was originally a granite, in some places of normal or medium grain, and in others having a coarser grained porphyritic or pegmatitic development, or at least would have crystallized out as such had not the movements in question intervened.

Moreover, very important light is thrown upon the conditions under which these movements took place by the study of great glaciated surfaces of these rocks. In the foliated varieties—as, for instance, that about Kasshabog lake in the Methuen batholith—a little corrugation is often seen in the foliation along a certain line, and when this becomes very sharp, and the little fold is about to pass into a fault, instead of a sharp fracture developing, the line of fault becomes filled with a coarser pegmatitic facies of the gneiss. (See Figs. C and D, page 82.)

Similar coarse strings sometimes appear running for short distances parallel to the foliation, and sometimes cross it in the form of little dikes. They appear wherever there is any evidence of rupture in the original rock, as marked by an interruption of the foliation. When, for instance, an amphibolite inclusion in the gneiss breaks apart, instead of the normal gneiss passing into the narrow crack between the fragments, pegmatite is developed in the fissure. But when the fragments are carried further apart, the gneiss flows into the space between them. These pegmatitic strings are often replaced by, or pass into, coarse strings or veins

Fig C

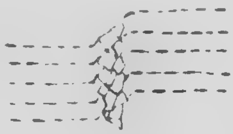


Fig D

of pure quartz. These strings and veins show no signs of crushing and are, so far as can be seen, genetically identical with the larger dikes and masses of pegmatite which traverse these granite areas in great numbers, and which also run in swarms through any rock penetrated by the granite. In the great areas of red gneiss in this region, therefore, when the rock possesses a more or less distinct foliated structure, the following facts are demonstrable:

(1). The rock has undergone movements, and to these movements it owes its foliated structure.

(2). In the case of the foliated porphyritic varieties, before the movements took place the feldspar phenocrysts existed in the rock, otherwise they could not have been granulated, and in certain cases, as on Kasshabog lake, when the rock can be traced to a massive development, the phenocrysts in it can be seen to be intact.

(3). The mica was also there before the movements took place, because it partakes of and emphasizes the flow of the rock. It was clearly not developed along lines of especial movement or pressure, as it does not occur along any definite lines, but in faint ill defined *schlieren* here and there in the rock.

(4). A large proportion of the feldspar, and the quartz, in addition to the phenocrysts, if these be present, must also have

crystallized out before the movements ceased, because during the movements the rock, although to a certain extent plastic, as shown by the little corrugations above figured, was yet sufficiently solid and rigid to tear apart, or to break when the bending was too sharp or the movement too sudden. The isolated phenocrysts, moreover, would not have been broken down into granular material had they, during the movement, been floating freely in a glassy magma. There must have been some material already crystallized, which pressed upon them.

(5). About the time of the cessation of the movements the rock must still have been, as it were, wet with a residual remnant of uncrystallized magma composed of the elements of quartz and feldspar (and in some cases of tourmaline), as this oozed out, filling all cracks, fissures, and spaces of every kind in the rock, so soon as these were formed, the remainder crystallizing out in situ through the substance of the rock, thus completing its solidification.

(6). These cracks, rents, etc., or some of them, were developed before the rock was perfectly solid and hard, as shown by the fact that the contact between the pegmatite filling them and the mass of the rock is not always hard and sharp, but the two fade away into one another.

(7). The foliation in the case of the Kasshabog area was completed before the latest dikes and pegmatite masses were formed, since they often cut across the foliation of the rock, and are not themselves foliated or granulated. In other parts of the area, however, as in the southwestern corner of the Haliburton sheet, and also in the case of some of the pegmatites cutting the crystalline limestone in the township of Burleigh, there is evidence, in the foliation of the pegmatite, and in its being pulled apart, that the movements did not entirely cease in the area as a whole, until after the injection of certain of the pegmatite dikes at least. While, therefore, the granite may have begun to move into its present position before crystallization commenced, the movement continued while crystallization was going forward, and during the successive stages of consolidation, when the mass became a stiff paste, filled with the products of crystallization, and lasted until it was nearly solid. It was during these latter stages of the movement that its present structure was chiefly impressed upon

it.[1] The final act of consolidation consisted of the crystallization of the last remnants of the magma, partly in the substance of the rock itself, thus completing its solidification, and partly as pegmatite, in places where it had oozed out into the fissures and cracks formed in the stiff paste-like or solid rock by the final movements, some of these probably incident to contraction or cooling. The pegmatite thus was not a later rock deposited in cracks and fissures of the gneiss after the entire cessation of the movement in the whole mass, but represents the product of the crystallization of the last portions of the magma which survived in a liquid state; just as during the crystallization of a mixed mass of fused metal, an eutectic alloy of two of the metals present will frequently remain fluid longest, and may be squeezed out of the nearly solid mass before the final solidification. In this connexion it is of importance to note that pegmatite, in the form of graphic granite, has precisely the structure of such an eutectic alloy.

It is impossible, in the present condition of our knowledge, to state definitely the reason why these pegmatitic masses should be prevailingly coarse in grain, but Michel Levy's conjecture that it is due to a more abundant supply of mineralizers, chiefly water vapour, seems to be the most likely explanation.

The dikes are not, however, always coarsely crystalline: they vary considerably, and often rapidly in grain, from place to place in the same dike, being in some places of medium grain, and elsewhere very coarse. Many of them about Jack lake, in the township of Methuen, are made up chiefly of a more or less normal granite, while almost all the great granite areas contain, as has been mentioned, a great deal of coarsely crystalline material, essentially pegmatite, throughout the body of the rock. If, as Brogger supposes, the vapour dissolved in the mass gradually

[1]For other examples of granite gneisses whose foliation has originated in movements of the magma while cooling, see.

Lawson, A. C., Geol. Rainy Lake Region. Ann. Rep. Geol. Surv. Can., Vol. III, 1887-88, p. 139 F

Daly, R. A., Studies on the so-called Porphyritic gneiss of New Hampshire. Jour. of Geol. 1897.

Westgate, L. G. A granite gneiss in central Connecticut. Jour. of Geol. No. 7 1899.

Barlow, A. E., Ann. Rep. Geol. Surv. Can., Vol. X, 1897. Part I, p. 60, et seq.

Klemm, G. Weber die Entstehung der Parallelstructur im Quartz porphyr von Thal in Thuringen. Ver. fur Erdkunde zur Darmstadt. iv. Heft 20. 1899. (ref. Neues Jahr. fur Min. etc. ii, 2. 1901. p. 225.)

concentrates in the still liquid residuum as the magma crystallizes, and the presence of the vapour tends to produce a coarsely crystalline habitus, the final remnants of the mother liquor in which the vapour would become concentrated, by the crystallization of the mass of the rock in the form of anhydrous minerals, and which was squeezed out into cracks and fissures in the granite itself, or in the surrounding rocks, which it penetrates, would naturally tend to take upon itself a very coarsely crystalline development. This seems to be an explanation of the phenomena, which is borne out by a study of the field at present under discussion.

Much of the grey gneiss also shows signs of having been granulated, as, for instance, the great developments about Red-stone lake, in the township of Guilford; but in this rock the tendency to a coarse-grained development does not seem to have been so prevalent, and hence the presence of large feldspar remnants is less common, and the evidence of granulation is thus not so pronounced.

The irruption of the granitic material in the manner above outlined, namely, when the rock had the consistency of a stiff paste, would tend to produce movements which were very slow and gradual. This appears to have been the case in all parts of the area, and a striking instance of it is afforded by exposures in the southern portion of the township of Monmouth. Here, the limestone belt which crosses the township is resolved into a mass of fragments, great and small, by the uprising of the granite beneath it. The separated fragments of the invaded rock are not irregularly displaced, as in the case of an ordinary intrusion, but have been slowly separated and carried apart, the curving pattern of their original strike being distinctly traceable in the fragments, even when these are widely separated from one another.

That this movement in the granite did not take place after the rock had solidified is further borne out by the fact that it did not follow lines or directions of shearing, but is seen throughout the whole mass of the rock, following elaborate flowing curves, which in several cases close upon themselves in concentric circles, from the centre of which the plane of the foliation dips away in every direction. This structure is identical with that observed and so well described by Lawson, in the granite-gneiss of the

Rainy Lake region.[1] "This circular trend of the strike of the planes of foliation of the gneiss is constant in a zone which has a considerable breadth measured on the radii of the circles, or in a direction transverse to the strike. . . . The simplest explanation that suggests itself to account for the structure is that of an upheaving force acting on a plastic mass, such force acting with greatest intensity in the vertical line which would correspond to the axis of the cone or dome. This would correspond to an anticlinal dome in ordinary bedded formations. With this difference, however, that in the latter the structural planes existed as planes of bedding prior to the application of the force which bulged it into a dome, whereas in the case of this Laurentian gneiss, all the evidence goes to show that the structural planes are the result of such upheaval, and a differentiation from the homogeneous character of the rock, produced by the deformation incident to it."

Furthermore, there is no development of the secondary minerals found in regions of ordinary dynamic action, and it is impossible to conceive of a solid rock, under any conditions of pressure, sustaining the relations to the amphibolite which this gneiss displays as described in the last section. It is certain, from a very careful study of the whole area, with this special question in view, that the granite-gneiss is not an original floor on which the other rocks of the area were deposited, and which was folded up with them by subsequent crustal deformation when all were in a solid state. It has, on the contrary, invaded, torn to pieces, and altered the other rocks, while it was in a fluid or semi-fluid condition. The rise of the batholiths probably began when the granite was in a molten condition, and thus capable of exerting extreme disruptive and metamorphic action, but was continued very slowly by the gradually cooling and crystallizing magma, the force being partially transmitted through the crystalline minerals of the pasty mass, thus crushing them, or flattening them out by movement along their gliding planes, according to the character of the mineral affected and the direction of the motion; the motion finally ceasing when the rock became solid by the final crystallization of the residual magma.

[1] Report on the geology of the Rainy Lake region. Ann. Rep. Geol. Surv. Can. (N. S.), Vol. III, 1887-88, p. 116F.

The whole character of the granite-gneiss and its contact relations bears a striking resemblance to the occurrences described by Lawson, in the region to the west of Lake Superior, and above referred to, except that the granulated and augen gneiss structure, which is so universal in the district at present under discussion, does not seem to be so prevalent in the western representative.

There seem to be no reasons derived from the study of this region which would necessitate the rejection of the view put forward by Lawson to account for the geological relations of the granite-gneiss to the district west of Lake Superior, namely, that this rock represents the original crust upon which the overlying rocks had been laid down, but which by a subsequent rise in the geothermal lines had become remelted and had invaded the overlying strata. Possibly the granite-gneiss represents the original crust in this Haliburton district also; it now, however, presents the characters of a body of intrusive rock.

CONTACT PHENOMENA ALONG THE BORDERS OF THE AREAS OF GRANITE-GNEISS, MORE PARTICULARLY WHERE THIS ROCK BREAKS THROUGH BODIES OF LIMESTONE.

Along the borders of the various areas of granite and granite gneiss contact action is pronounced. If the invaded rock be amphibolite, fragments are torn from it and are found scattered through the gneiss, giving rise to inclusions presenting the various characters already described.

When the granite-gneiss invades bodies of the limestone, on the other hand, the changes produced and the phenomena resulting from the intrusion are more varied. The products of alteration may be divided into two classes: (1) The alteration of the limestone into masses of granular pyroxene rock, usually containing scapolite, or into bodies of a fine-grained aggregate of scales of a dark brown mica. (2) The intense alteration of the limestone along the immediate contact into a pyroxene gneiss, or an amphibolite. The alterations of the first class may be considered as due to the heated waters or vapours given off by the cooling magma, that is, to be of pneumatolitic origin; while the alteration products of the second class probably result from the more immediate action of the molten magma itself. The products of

these two classes of alteration have a good deal in common, and naturally pass into one another.

The most striking product of the first class is a granular, pale green pyroxene rock, which occurs in the limestone at or near its contact with the granite. It was for this pyroxene rock, which is also very commonly associated with the Laurentian limestones in the Province of Quebec, as well as in many other places in eastern Ontario, that T. Sterry Hunt proposed the name pyroxenite. Under this name, however, he included certain highly pyroxenic basic intrusive rocks found in the same and other districts, which differ entirely in appearance and origin.

This pyroxene rock resulting from the alteration of the limestone, often varies considerably in texture from place to place, but is usually medium in grain and granular in character, the sahlite individuals of which it is composed being short and stout, and with a hypidiomorphic development.

Associated with this pyroxene in the rock are found black mica, hornblende, scapolite, epidote, garnet, sphene, spinel, tourmaline, calcite, apatite, and even quartz, and feldspar, as accessory constituents. In some cases minute zircon crystals also occur. Certain metallic minerals, notably pyrite, molybdenite, and pyrrhotite, are common in these pyroxenites. Of these minerals, the mica and hornblende especially have a tendency to occur in segregations, nests, or elongated masses composed of very large individuals, so large that the mica in this form has been mined at several points in the area, as for instance on the line of the Irondale, Bancroft and Ottawa railway, where it crosses lot 7, concession XXII of the township of Cardiff; where mica crystals having cleavage surfaces 2 feet by 2½ feet across have been obtained. The calcite when present in the rock is usually in the form of very coarsely crystalline aggregates, cementing the other constituents together, and into which the other minerals grow in the form of perfect crystals with excellent terminations. This calcite represents portions of the original limsetone, which have survived in an unaltered condition, except that they have become more coarsely crystalline. When the calcite has been subsequently removed in solution by percolating waters, empty spaces result, which when broken into are found to be lined with beautiful crystals of pyroxene and other constituents of the rock.

One of the largest occurrences of this pyroxenite met with in the area is that situated on lot 3, concession I of the township of Harcourt. It is about 100 yards wide and 250 yards long, forming a low hill, surrounded on three sides by the granite-gneiss, the contact on the fourth side being covered by drift. It occurs at the side of one of the smaller limestone areas of the Bancroft sheet, which is completely surrounded by the granite, and there can be little doubt, from its character and mode of occurrence, that it represents a detached mass of the limestone now completely altered into the pyroxene rock. The strike of the gneiss on either side is N. 20 W. which is the prevailing strike in that district but at the extremity of the mass, near the shore of Lake Farquart, the foliation is seen to wrap around the mass, striking in one place N. 70° E. When the rock is examined under the microscope it is seen to be composed almost exclusively of a pale hypidiomorphic, non-pleochroic pyroxene, with a high extinction angle. A very small quantity of a pale green hornblende is also present, and a few minute brownish zircons (?) A small amount of calcite occurs in the corners between the pyroxene individuals, which grow into it, with good crystalline forms. These are the only minerals present in the rock itself, with the exception of a colourless mineral in fibrous, radiating forms, which resembles a zeolite, but which is present in very small quantity. The pyroxenite is here traversed by little strings of feldspar, in which, in several places, little Baveno twins may be seen. The mass is also seamed with strings of pyrite and molybdenite. These two minerals are intimately associated, and the veins, while narrow, in many places afford excellent specimens of these species, plates of molybdenite as much as two inches across being common. Pyrrhotite, tourmaline, and sphene occur with them, though much less abundantly.

At many other points on the shore of Lake Farquart, the crystalline limestones are seen to be cut by the granite-gneiss, and are filled with grains of pyroxene, brown mica, etc., showing all possible transitions from a pure limestone to a granular green pyroxenite

By the side of this same lake, about the line between lots 5 and 6, concession II of Harcourt, there is a great exposure of another variety of pyroxenite, which abuts against a mass of the

intrusive granitic rock, and is, to all appearance, also a body of altered limestone. It rises from the waters of the lake, forming a cliff 145 feet high. Instead of the green colour usually seen in these pyroxenites, this rock has a peculiar pinkish brown colour. It is of medium grain, rather massive in character, and is very heavy (specific gravity = 3·34), and looks like a garnet rock, but is, of course, much softer. Under the microscope it is seen to be composed of a monoclinic pyroxene, with faint pleochroism, in reddish and greenish tints, an extinction angle of 43°, and a strong dispersion of the bisectrices. With this there is associated in much smaller amount a brown hornblende, which occurs in the pyroxene individuals, sometimes with good crystalline outlines, but usually in allotriomorphic individuals. The rock also contains epidote in many places, as well as very small quantities of pyrrhotite, sphene, calcite, and spinel.

Another striking example of the alteration of the limestones by granite is that afforded by the intrusion in the northeast corner of the township of Tudor. Along the southern margin of granite, on concession XIX of Tudor, the limestone has been altered, for a distance of at least 100 yards from the contact, into a belt of reddish green rock, consisting of epidote, garnet, and pyroxene, with here and there a little nest of actinolite fibres, and a few little surviving remnants of calcite, into which the other constituents grow, with good crystal terminations. In microscopic appearance this rock strongly resembles that just described from concession of Harcourt, but in the Tudor rock the reddish mineral is garnet, which, while varying considerably in amount from place to place, constitutes a considerable proportion of the rock, the occurrence being one which would afford garnet in amount sufficient for its employment for economic purposes.

The green pyroxenite is also seen in a great many places along the course of the narrow limestone bands which cross the townships of Harcourt and Herschel and the northern portion of Cardiff. These bands, being narrow and exposed to the action of granite on either side, are in a very highly altered condition, and in some cases the mode of occurrence of the pyroxenite shows that it was developed in the limestone before the completion of the movements which gave rise to the twisting and contortions of the latter. One of these localities, where the development of the pyroxene rock can be especially well seen, is on the Irondale,

Bancroft and Ottawa railway, along the line between lots 32 and 33 of the township of Faraday. Here the granite, having a pegmatitic development, cuts through the limestone and encloses great masses, altering it wherever they come in contact, into a green pyroxenite. Streak-like masses of the pyroxenite are also seen in the granite near the contact. The limestone also, for some considerable distance back from the contact, holds masses of the pyroxenite containing black mica, which latter mineral is also found independently in the limestone in some abundance at other places along the contact. In the masses of the pyroxenite, which occur in the granite, especially when these are large, scapolite is frequently found, and the pyroxenite, in places, holds cavities lined with very perfect pyroxene crystals. These are formed, as has been mentioned, by the large pyroxene crystals growing into the calcite of the limestone fragments included in the granite, followed by the removal of the calcite which remains, by solution in percolating waters. Under the microscope, the pyroxenite presents the usual characters, and contains, in addition to the pyroxene, a very small quantity of biotite, apatite, perthite, and a few minute crystals of a mineral apparently zircon.

Farther to the east, wherever the limestone is exposed on either shore of Baptiste lake, it is seen to be filled with grains of serpentine, mica, apatite, and various other secondary minerals, and in many places to pass over into the same green pyroxenite, which is very abundant, especially on the western half of the lake. This pyroxenite frequently holds nests of black mica scales, the mica in places becoming coarsely crystalline, plates several inches in diameter being found. At several points on lots 22 and 25 of concession VI of Herschel, these coarse segregates have been worked to a limited extent for the mica. In places, scapolite in considerable amount, and at some places in large individuals, occurs associated with the pyroxene, and often intergrown with it in granophyric forms. A deep green hornblende is also seen occasionally running th[illegible]gh the pyroxenite in narrow veins, as if it had developed along cracks.

Many other occurrences of the same granular green pyroxene rock are found, as alteration products of the limestones at their contact with the granites in all parts of the area. Of these it will be sufficient to note those occurring at the following localities:

Township of Anstruther, concession VIII.—Here it occurs as masses in the granite of the central batholith, where along the north shore of Eel lake the latter cuts through the limestones and amphibolite. Under the microscope the rock is seen to be composed exclusively of pyroxene, with a very small amount of dark mica.

Township of Monmouth, lots 8 to 14, concessions IX and X. Here, along the Irondale, Bancroft and Ottawa railway, there are numerous exposures of the limestone cut by pegmatite dikes, and by them converted into pyroxenite along the contacts.

Township of Stanhope, lot 22, concession XIII.—The pyroxenite here occurs on a point running out from the lake shore on the south half of the lot. It is bounded by pegmatite gneiss on one side, while the water of the lake conceals the other boundary. The mass is elongated in shape, and is exposed for a width of 20 feet. Its connexion with the limestone is thus not seen, but it may be an included block completely altered. The examination of a thin section shows it to be composed of pyroxene and hornblende—both green in colour, and occurring in about equal amounts intergrown with one another. Small quantities of apatite and quartz are also present.

Township of Wollaston, lot 15, concession IX. Granular green pyroxene rock occurs associated with iron ore at the Coehill mine, as mentioned on page 205, where it is probably also an alteration product of limestone.

Township of Livingstone. South shore of a large island in Hollow lake.—This occurrence has already been mentioned on page 70. At the east end of the island there is exposed for a distance of some 50 yards along the shore a mass of very hard, green pyroxenite, cut by several large pegmatite dikes. This rock bears a marked resemblance to the rocks described above as altered limestones, and although no limestone occurs near it, it is quite possible that it may be a mass of altered limestone, floated along in the granite rock of the country in the same way as the amphibolite inclusions, which occur scattered all through the gneiss of this district. When examined under the microscope about nine-tenths of the rock is seen to be composed of a very pale green pyroxene. With this there is associated a considerable amount of deep brown mica, scattered through

the rock in little flakes. Very small amounts of rhombic pyroxene, hornblende, and plagioclase make up the sum of the constituents.

This rock bears a strong resemblance to the pyroxenites formed by the alteration of the limestones above described, both in structure and composition. It may, however, be an igneous rock very rich in pyroxene.

Township of Anson, lot 12, concession III.—South end of bay in Big Bobs lake. The granite-gneiss holds fragments of the same green pyroxenite, with little scales of deep brown mica scattered through it. The limestone occurs in large exposures on the other side of the bay, where it holds lumps of white pyroxene, often surrounded by zones of serpentine, about which are outer zones of green mica.

These pyroxene rocks are identical in character with those which are so intimately associated with the apatite deposits of Ottawa county, Que., and of the Perth district, Ont. Those from the former district have recently been described in detail by Osann,[1] and shown by him to result from pneumatolitic action connected with intrusion of certain basic igneous rocks, and thus to be related genetically to the "apatitbringer" of the Norwegian apatite districts.

As has been stated on page 88, apatite is very frequently found in association with these pyroxene rocks in the area at present under consideration, but only in one or two places in amounts that can be considered as of economic importance.

The other product of pneumatolitic action emanating from the granitic intrusion which has been mentioned, is a rock composed of an aggregate of small leaves of a very deep brown or black mica, and is less common. The locality where this is seen in its greatest development is on the road running east from Deer lake, in the township of Cardiff, into the township of Faraday. The rock is first met with on the east side of lot 33 of the latter township, and, extending across lot 32 and the western side of lot 31, where it becomes more and more calcareous, it finally passes into the limestone which occupies the eastern side of this lot. A similar mica rock, developed from the limestone, is seen on the railway to the west of Wilberforce, in the township of Monmouth. These mica rocks almost invariably contain more

[1] Notes on certain Archæan Rocks of the Ottawa Valley. Ann. Rept. Geol. Survey of Canada. Vol. xii. Part O (1902).

or less calcite disseminated through them, which, on exposure to the weather, is dissolved, the weathered surface of the rock being thus resolved into a soft mass of small scales of black mica. The chemical nature of this mica has not been determined, but it is probably some variety containing a considerable amount of fluorine, and probably some lithia, such as occurs in limestones about granite intrusions in other parts of the world.

Still another curious rock, which from its mode of occurrence seems to be a completely altered limestone, was found in large exposures in the townships of Harcourt, Dudley, and Bruton. This rock, on account of the fact that in composition it is an anorthosite, has been indicated by the colour representing gabbro on the accompanying maps. In Harcourt this rock is intimately associated with the white crystalline limestone, and often contains strings of the green pyroxene rock above described. It is generally white in colour, bearing a strong resemblance to marble, and is cut by numerous arms of the intrusive gneiss of the region, and by dikes of pegmatite. Its stratigraphical relations here, and in the adjacent township of Dudley, make it almost impossible to consider it as other than an alteration product of the limestone. The rock is coarse in grain, and in these two townships it often contains a good deal of a dark green hornblende, arranged so as to give the rock a distinct foliation, causing it to bear a strong resemblance to a flaser gabbro. On the other hand, when this dark constituent is present in small amount, as it frequently is, the rock bears a striking resemblance to the white albite rock, which is associated with, passes into, and forms a local development of the nepheline syenites occurring in other parts of the sheet. A very careful search over large weathered surfaces of the rock where the presence of nepheline can best be detected, failed, however, in any case to reveal the presence of this mineral. Another marked difference between these two rocks was revealed upon closer study, namely, that in the case of the rocks at present under consideration the feldspar is never albite, but always labradorite. Scapolite is also frequently present, often in large amount. Specimens of this rock from two localities in Harcourt, and from one in Dudley, were examined under the microscope.

The first of these was from lot 4, concession III of Harcourt. The rock is coarse in grain, and has a well marked foliated, or flaser structure. It consists of an allotriomorphic aggregate of

plagioclase, scapolite, hornblende, and biotite. A separation of the constituents of the rock by means of Thoulet's solution shows that the plagioclase, which is the most abundant constituent of the rock, has a specific gravity of between 2·65 and 2·69, and belongs to the species labradorite. The scapolite, which is present in about equal amount, shows the cleavage, parallel extinction, and other optical properties which characterize the mineral. It has a specific gravity of over 2·69, which, taken in connexion with the very high double refraction which the mineral displays, indicates that it is a scapolite rich in lime. It sometimes shows an approach to idiomorphic development, but is usually allotriomorphic. The hornblende is also present in very considerable amount, and shows a marked pleochroism in green and yellow tints. The biotite is a very subordinate constituent, only a few little leaves occurring in the section.

The other specimen was collected on lot 4, concession III of Harcourt. It is rather finer in grain, but still has a distinct gneissic structure. Under the microscope it is seen to be composed of the same constituent minerals, and to possess a distinct allotriomorphic (or pavement) structure. The scapolite, however, is much less abundant. Both the hornblende and mica are very pale green in colour, and are present in about equal amount.

The specimen examined from Dudley was from lot 24, concession VI of that township, and was found to be essentially identical with that from lot 4, concession III of Harcourt, but to be proportionately richer in hornblende, and holding more or less pyrite.

In the township of Bruton this rock is found as a band from one-half to three-quarters of a mile wide, enclosed in the great northern gneiss and conforming to it in strike. On coming down the York branch from the township of Clyde, the rock was first found on lot 21, on the line between concessions V and VI, where it forms the upper part of a large bare hill, which rises to a height of 216 feet above the river at its foot, the lower part of the hill being composed of orthoclase gneiss, of the so-called conglomeratic type referred to on page 78, and which has evidently been subjected to great movement. The bare top of the hill is as white as if it were composed of marble, and the rock on the fresh fracture bears a striking resemblance to the albitic development of the nepheline syenite. No nepheline, however, could be detected

in it, after a very careful search. It contains a small amount of dark hornblende and mica, arranged in little streaks marking the foliation of the rock, and is penetrated by a number of dikes and arms of a crushed pegmatite which ramify through it. The white rock was evidently less plastic than the pegmatite under the movements which gave rise to this crushing, for it is seen in many places to be broken into little blocks, and faulted, the blocks in question being separated by the granulated pegmatite above mentioned. In a few places strings of the green pyroxenite described above are found in the rock.

This belt of rock was found to cross the Lake of Two Rivers on lots 21, 22, and 23 of concession V, and going west to underlie the northern end of Little Rock lake, on lots 19 and 20 of concession IV, while still farther west it was found again forming the north shore of Kingscote lake, on lots 14 and 15 of concession V. It was not followed farther west, neither was it traced to the east of the Lake of Two Rivers. A specimen of the rock collected on lot 15, concession V, was examined microscopically, and a separation of it was also made by means of Thoulet's solution. Under the microscope the rock is seen to have an allotriomorphic structure, and to be composed almost entirely of a clear, fresh, well-twinned feldspar, which is shown by the separation to be labradorite, as in the case of the specimens from Harcourt and Dudley. A certain amount of scapolite is present, having the same characters as in the case of the Harcourt rock, while the most abundant iron-magnesia constituent is a biotite, associated in places with a little muscovite, and often partially altered to chlorite. A very little pale green hornblende, zoisite, sphene, and calcite are the only other constituents of the rock.

The question as to the origin of these curious rocks is one which, in the present condition of our knowledge, cannot be definitely settled. In Harcourt and Dudley, as stated above, their relations to the limestones along the contact with the granites are such as to render it almost certain that they are produced by the alteration of the former rock. In the case of the Bruton occurrence, on the other hand, the rock occurs in the gneiss some miles from the nearest contact, but it is, nevertheless, quite possible that here also it represents a portion of a completely altered limestone band, which has sagged down into the batholith and been torn apart by the movements of the latter.

The alterations of the second class, whereby the limestones are converted into pyroxene gneisses and amphibolites, are especially well seen in certain parts of the area, where the granitic magma shatters the invaded rocks, and floats away the fragments in its moving mass. In shape and appearance, and in their relations to the granite, these inclusions, when the granite invades amphibolite or allied rocks, are exactly like those before described. The gneiss can be seen to invade the areas of these rocks, to tear off fragments of them, and carry these away. The whole process is displayed in the most striking manner. No finer example of lit-par-lit injection, for instance, could be found anywhere than that seen in the southwest corner of the township of Burleigh, and the adjacent portion of the township of Harvey, on the road between Burleigh Falls and the Silurian outlier a short distance to the north; or in the district about Maxwells crossing, in the township of Glamorgan.

In those parts of the area where the batholiths break through the limestones, small isolated areas of highly altered limestone are occasionally seen in the gneiss. Such areas are shown in the Haliburton map, as for instance, in the townships of Anson and Stanhope. It is a remarkable fact, however, that while these limestone areas, and the margins of the larger bodies are clearly penetrated and shattered by the granite, and traversed by great dikes of this rock, and while in the case of other rocks under similar conditions the granite is frequently crowded with fragments of the invaded rock, it is very rarely indeed that fragments of the limestone are found in the granite. This fact is very noticeable in the case of the great Glamorgan batholith, whose eastern limit lies in the township of Glamorgan, and which is crossed by the Buckhorn road going north from the village of Gooderham. The batholith here breaks through the great body of limestone occurring in northwestern Monmouth, and repeated examinations of the contact were made, in order to ascertain, if possible, the cause of this apparent anomaly. Where the Buckhorn road crosses the line between concessions IX and X of Glamorgan, the granite is seen holding many inclusions of amphibolite, and a careful search led to the discovery among those of but a single fragment of coarsely crystalline limestone, on one side of which there was a mass of a light coloured amphibolite, which had apparently been produced by its alteration. This latter rock, under the micro-

scope, was s[illegible] [illegible]nsist essentially of pale green pyroxene, a deepe[illegible] [illegible]nde, and a very clear feldspar. The feldspar ma[illegible] [illegible] one-half of the rock, while the pyroxene and hornbl[illegible] [illegible] present in about equal amounts. This feldspar is sometimes twinned polysynthetically, and is probably all plagioclase. Microcline, calcite, scapolite, and sphene are present as accessory constituents.

Leaving the Buckhorn road and going east toward the margin of the granite intrusion, along the road running on the line between concessions IX and X, the amphibolite inclusions become very numerous, and often present the appearance of portions of contorted beds broken away from a series of stratified rocks. No limestone fragments, however, were found among them. Still farther east, however, about lot 27, when the amphibolite fragments were carefully examined, some of them were seen to contain crystalline limestone in little interbanded layers and streaks, conformable to the foliation of the amphibolite, and partaking of the complicated twisting to which it has been subjected. Masses of this double rock are enclosed in the granite, and the amphibolite occurring in them is to all appearances identical with that forming separate amphibolite inclusions (see Plate XII, Fig. 1). Still farther east the limestone comes in, in force. The field evidence is scarcely susceptible of any interpretation other than that, under the influence of the granitic intrusion, the limestone has, in the zone of most intense action, been altered into an amphibolite.

A series of thin sections of these rocks from lot 27 were prepared and examined microscopically. The limestone, which is coarsely crystalline, was found to be composed chiefly of large individuals of calcite, which show no evidence of twisting or shearing. Mica, pyroxene, hornblende, sphene, and scapolite occur as accessory constituents. The mica is of a rather deep brown colour, and has a very small axial angle. The pyroxene is very pale green in colour, and occurs in rounded grains. The hornblende is somewhat deeper green in colour than the pyroxene, but does not differ greatly from it in appearance; while the sphene is deep brown in colour like that seen in the amphibolites, and also occurs in more or less rounded grains. The scapolite is present only in very small amount. The limestone is indistinctly banded, some bands being rather finer in grain and richer in pyroxene, while others are coarser in grain and contain more mica.

Fig. 1. Amphibolite resulting from alteration of limestone cut by pegmatite. Eastern border of Glamorgan batholith, near [illegible]

Fig. 2. Limestone passing into pyroxene gneiss and amphibolite cut by granite. Southern border of Glamorgan batholith. Maxwells crossing.

The amphibolite, which is so intimately associated with the limestone, and which seems to have been derived from its alteration, when examined under the microscope is seen to be a highly feldspathic variety, being composed largely of feldspar. This, as in the case of the amphibolites which have already been described, and which occur as inclusions in the gneiss of the great northern area, is in part twinned polysynthetically and in part in untwinned individuals. Here, as in the amphibolite above referred to, it is probably all plagioclase. The rock, however, contains no calcite. Pyroxene, hornblende, sphene, and scapolite are also present, as well as a grain or two of magnetite and quartz. The pyroxene and hornblende are of the same varieties as those found in the limestone, but are present in much larger proportions than in that rock. The amphibolite has a somewhat indistinct banded character, some of the bands which are paler in colour being richer in pyroxene, while the darker bands are richer in hornblende. The scapolite occurs only in those bands which are rich in pyroxene but contain no hornblende. The structure of the rock is allotriomorphic. The amphibolite thus differs from the limestone, mainly in the fact that feldspar is present instead of calcite, and that the proportion of the iron-magnesia constituents is greater.

Another variety of darker amphibolite which occurs associated with the limestone at this same locality was found to be composed essentially of hornblende and feldspar, the other constituents of the amphibolite above described being present as accessory constituents, with the exception of the scapolite, which is absent.

The relations of the same batholith to the limestone series are also well seen along the southern contact, on concessions VI and VII of the township of Glamorgan, between lot 5 and lot 23. The great belt of almost pure marble which crosses almost the entire width of the township on concessions IV and V is excellently exposed on Contau lake, on the south shore of which it is developed as a dolomite, and on the Kinmount road to the south of the lake. The northern limit of the marble, from lot 12 to lot 23, nearly coincides with the northern limit of concession V. Here on the concession road, locally known as Ken street, it is succeeded by a greyish rock, which varies somewhat in character from place to place, but presents the appearance of a light coloured amphibo-

lite. This is cut by a great number of dikes and masses of pegmatite, and is also traversed by an immense number of little strings of pegmatite, which swarm through the rock in all directions. When the invaded rock has a foliated structure these are often seen to cut across the foliation, as if they had been intruded subsequent to its development. In some places little streaks or bands of the limestone, or bands of the rusty weathering gneiss so often associated with the limestone, can be seen in this grey rock. The field evidence is strongly in favour of regarding this grey rock as the limestone, altered along the margin of the batholith by the immense amount of granitic material which has been intruded through it, the little streaks and bands of limestone which occur in it being survivals of the original rock.

This belt of amphibolite varies in width from one-half to three-quarters of a mile, and it represents the brecciated zone which is seen on the eastern side of the batholith, the invaded strata here in the south, while thoroughly shattered and penetrated by much granitic material, not being so completely disrupted as along the eastern end of the batholith, in a continuation of the line of maximum uplift.

Two specimens of this amphibolite collected on Hell street, from lots 18 and 19, concession VI of Glamorgan, respectively, were examined under the microscope, and proved to be almost identical in character. They were found to consist chiefly of a green hornblende, and a colourless felspar. There was present, in addition, a certain amount of a very pale green pyroxene, and a brown biotite, the latter usually in long straight laths, often traversing several individuals of the other constituents. A little brown sphene and apatite are the only other minerals in the rock.

The pyroxene is often filled with minute spots of hornblende, as if it were undergoing a change into the latter mineral. The feldspar makes up about one-half the entire rock and is usually very clear and fresh in appearance. In the specimen from lot 18, only a minority of the grains show polysynthetic twinning, but they are probably all plagioclase. In that from lot 19 a little microcline is present in addition to the plagioclase, and the rock contains no biotite. In neither rock has any calcite survived, nor is there any scapolite present. In structure, and in the character of the hornblende, pyroxene, and sphene which they contain,

Limestone (coarse-grained) and penetrated by a small granite dike (in centre). Southern border of Glamorgan batholith, Maxwells crossing

—

these rocks are identical with those described below from Maxwells crossing. They also resemble those rocks very closely in general appearance.

The character of the northern limit of the great limestone belt where it comes against the southern margin of the batholith, can be well studied along the road which approximately follows the line between concessions VI and VII of Glamorgan, across lots 5 to 20, on the south side of the Burnt river, while a section across the contact, into the heart of the batholith, can be seen on the road which runs north from Maxwells crossing to Bark lake, on concessions X and XI. The contact rocks are well exposed in the railway cutting at Maxwells crossing, on lot 5, concession VI. Here the grey amphibolite above mentioned consists of thin lighter and darker bands, breaking up into slab-like masses, and is often interstratified with narrow bands of impure limestone. The limestone bands fade away imperceptibly into the amphibolite, the latter being undoubtedly produced by the alteration of the limestone. These rocks are invaded by the granite, traversing them in apophyses, which swarm through them in all directions, often running parallel to the banding, and elsewhere cutting across it (see Plate XII, Fig. 2, and Plate XIII). Here again the alteration is due not only to the proximity of the main mass of the batholith, but to the immense amount of granitic material which occurs intruded through the series, sometimes in large masses, but very frequently in thin bands which have found their way in between the beds of the invaded limestone, changing it into amphibolite, and presenting a typical instance of lit-par-lit injection. The granite, furthermore, not only penetrates this amphibolite series, but floats off masses of it, which, in the form of bands, streaks, and isolated shreds, are seen thickly scattered through the granite in the vicinity of the contact, and which, while less abundant, are found throughout practically the whole mass of this batholith, as mentioned below. The separate fragments of amphibolite, where completely surrounded by the granite, while clearly nothing more than masses of altered limestone, are rather harder, and have a more granitized appearance than the rock, which is still interstratified with the limestone. The fragments moreover sometimes have a somewhat flowing form, as if they had been subjected to a certain amount of movement when in a softened condition.

When examined in thin sections under the microscope, the limestone is seen to have passed into the rock referred to above as amphibolite, by the development in it of certain silicates. These in some places are so abundant that they have entirely replaced the calcite, while in others much of the original calcite still remains. The silicates belong to the following species: pyroxene, hornblende, sphene, scapolite, plagioclase, microcline, orthoclase, and quartz. The relative abundance of these minerals varies in different bands and in different parts of the rock. Their characters are as follows:

The pyroxene is rather deep green in colour and shows an absence of pleochroism. It is one of the chief constituents, being always present in large amount. It occurs in individuals, which are rounded in shape, never possessing crystallographic outlines, and seldom showing any approximation to crystalline form. In those varieties rich in calcite, the sections of the pyroxene grains are frequently nearly circular.

The hornblende, which is much less abundant than the pyroxene, is also green in colour, but the green colour is much deeper than that displayed by the pyroxene. The grains are similar to those of the pyroxene in form, but are usually less rounded, and it is intimately associated with the pyroxene, often forming adjacent grains, but there is no conclusive evidence that one mineral was derived from the other. It is strongly pleochroic.

The sphene is present only in very small amount, in the form of small rounded grains of a brown colour.

Scapolite is usually present in considerable amount. It polarizes in brilliant colours, is uniaxial and negative, and shows the usual microscopical characters of this mineral. In several of these rocks, the two sets of cleavage crossing one another at right angles, on the basal sections of this mineral, could be distinctly seen to be parallel to the prismatic faces, instead of being parallel to the pinacoids, as is usually supposed to be the case in scapolite.

The feldspars vary greatly in amount. In places they form a considerable part of the rock, while no scapolite is present. In other places the scapolite seems to take their place, and they are reduced to the rank of accessory constituents. All three varieties of feldspar mentioned often occur in the same specimen,

their relative abundance varying from slide to slide. The polysynthetically twinned plagioclase in some cases equals the potash feldspar in amount, but usually the potash feldspars seem to be rather more abundant.

The quartz is found only in a few of the thin sections, and is then present only in very small amount.

When the calcite survives, as it does in many specimens, it can be seen that the original rock had the character of a coarsely crystalline limestone, like those found elsewhere in the Laurentian. Under the action of the metamorphic processes the silicates have grown into it in the form of rounded grains, which, increasing gradually in size, have finally left the calcite merely as a filling of the surviving interstitial spaces. The grains are about the same size as those of the other minerals.

An examination was made of certain thin sections prepared from a suite of specimens of this amphibolite, collected from a series of exposures in the cutting on the line of the Irondale, Bancroft and Ottawa railway, at Maxwells crossing. Some of these less granitized in appearance and containing narrow surviving bands of calcite, and others of the harder and more altered varieties, show that in the former, pyroxene and scapolite accompany the hornblende and feldspars, while, as the alteration becomes more pronounced, these former minerals become less abundant, and eventually disappear, giving rise to a rock composed of hornblende and feldspar, associated with which a little biotite is seen in some specimens, with certain accessory minerals which are common to both rocks. Although, as above mentioned, no actual passage of pyroxene into hornblende could be definitely observed, the hornblende individuals often have a minutely serrated edge where they come against the pyroxene, as if they were gradually enlarging themselves at the expense of the latter mineral, and thus replacing it.

The rock, while possessing a more or less distinct foliation, has the pflaster, pavement, or mosaic structure characteristic of rocks which have resulted from recrystallization brought about by metamorphic processes. It presents no evidence of crushing, or of having been caused to move since its recrystallization took place. This structure is quite distinct, and different from that seen in the little injected bands of granite. In these, which are composed of quartz, microcline, orthoclase, and plagioclase, the

quartz occurs for the most part in thin leaves, with undulatory extinction, and the structure of the rock is suggestive of the mortel, or granulated structure seen in the granite-gneisses.

In this remarkable occurrence, therefore, the crystalline limestone can be seen, under the influence of the granite intrusion, to have changed into a typical hornblende feldspar amphibolite, passing through the intervening stage of a pyroxene scapolite-hornblende feldspar amphibolite (pyroxene scapolite gneiss).

Three specimens of these amphibolitic rocks, chosen to show three stages in this progressive change from limestone to amphibolite, were selected for analysis. The analyses were made by M. F. Connor, B.Sc., of the Geological Survey, Canada, the results representing in all cases the mean of two closely concurrent determinations. The results of these analyses are as follows: —

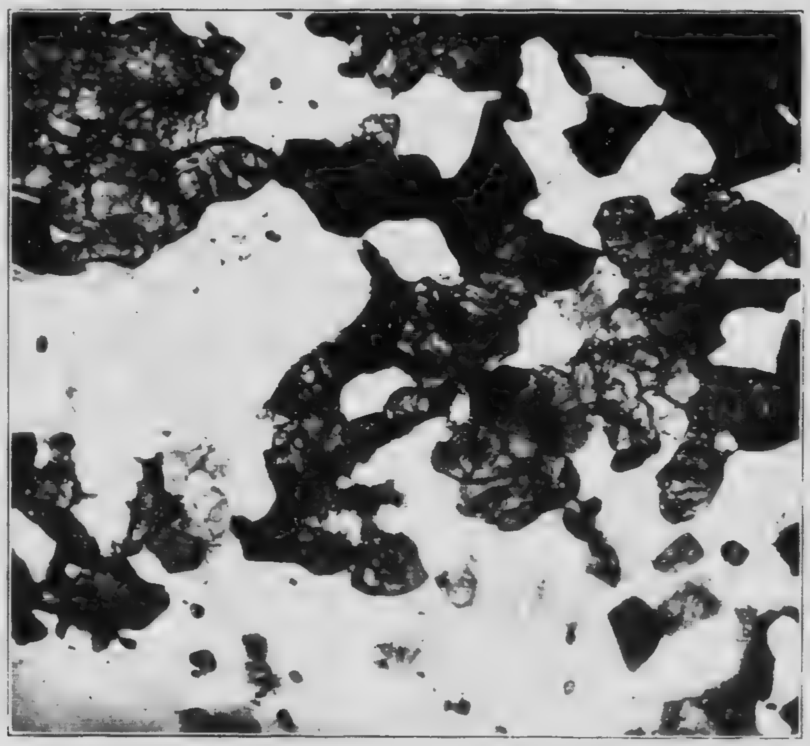
	No. 1 (a)	No. 1 (b)	No. 2	No. 3
SiO_2	32·88	50·20	50·00	50·83
TiO_2	0·49	0·75	0·82	1·10
Al_2O_3	9·04	13·80	18·84	18·64
Fe_2O_3	0·77	1·18	2·57	2·84
FeO	3·48	5·31	5·51	5·97
MnO		...	0·08	0·10
CaO	30·90	17·71	10·65	7·50
MgO	4·18	6·38	4·63	4·90
K_2O	0·85	1·30	1·18	1·83
Na_2O	1·17	1·79	4·46	4·22
CO_2	15·20	.	0·10	0·11
Cl	undet.		0·10	0·03
S	undet.	...	0·03	0·01
H_2O	1·08	1·66	1·00	1·40
	100·04	100·08	99·97	99·48

No. 1 represents the first stage of alteration, (see Plate XIV) and was made from a specimen which shows an alteration of narrow lighter and darker coloured bands. The specimen was broken across the strike of the rock, and thus included several of each of these bands, giving in this way an approximate average of the composition of the rock as a whole. Under the microscope the lighter coloured bands are seen to consist of calcite, pyroxene, and a little hornblende. In the darker bands the calcite is largely replaced by the silicates, the constituent minerals

PLATE XIV

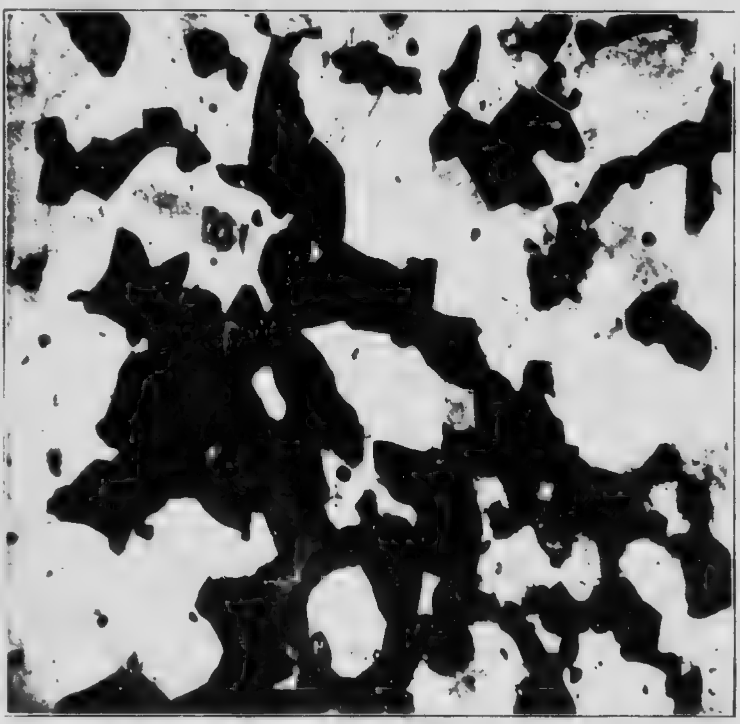
Microphotograph showing alteration of limestone to amphibolite (first stage). Maxwells crossing. Shows an allotriomorphic aggregate of augite, calcite, and feldspar. Ordinary light. Magnified 44 diameters.

PLATE XV



Microphotograph showing [illegible] stage. Maxwell's crossing. Shows [illegible] [illegible] Ontario [illegible] [illegible]

PLATE XVI



Microphotograph showing alteration of limestone to amphibolite (third stage). Maxwells crossing. Shows an allotriomorphic aggregate of hornblende with subordinate augite and plagioclase. A few small grains of sphene are also seen. Ordinary light. Magnified 44 diameters.

of these bands being scapolite, pyroxene, some hornblende, some calcite, and a little microcline. A very small amount of sphene is also present in the rock.

The analysis as given under No. 1 (a) represents the composition of the specimen as collected; that given under No. 1 (b) represents the composition of the rock as it appears when the calcite (determined by calculation from the amount of CO_2 present, and also by direct experiment) is deducted, and the amount of the remaining constituents is re-calculated on the basis of 100. No. 1 (b) thus shows th[illegible]ercentage composition of the silicated portion of the speci[illegible] to put it another way, it represents, except in the case o[illegible], the additions made to the limestone by the granite magma [illegible] first stage of alteration.

The rock contains 34·50 per cent of calcite, leaving 65·50 per cent of silicates. This silicated portion of the rock, as will be seen by comparing analysis No. 1 (a) with Nos. 2 and 3, bears a general resemblance to the composition of the two latter rocks, which represent the subsequent stages of alteration, the percentage of silica being practically identical in all cases.

No. 2 is the analysis of a typical specimen of the amphibolite (see Plate XV) which alternates with thin bands of the limestone at Maxwells crossing. It represents a second stage in the alteration, this particular specimen being practically free from calcite. Under the microscope it is seen to be composed of hornblende and pyroxene, more or less completely replacing each other in the alternate bands, together with a considerable amount of scapolite, plagioclase, and untwinned feldspar. The rock also contains many minute rounded grains of sphene scattered everywhere through it, but holds no iron ore, and no biotite.

No. 3 is the analysis of a harder variety, (see Plate XVI) being a typical amphibolite, and representing the last stage of the change. It occurs as an inclusion in the granite, in the same series of exposures as that from which the other specimens were taken. The field relations show that it has been derived from variety No. 2 by additional alteration. Under the microscope it is seen to differ somewhat from No. 2 in structure, the individuals of the several constituents showing a less marked tendency to a rounded outline than in the case of No. 2. In [illegible]

alogical composition also it presents certain differences, the pyroxene and scapolite having disappeared, and a certain amount of biotite having been developed.

A comparison of the analyses shows that the granite at first transfuses into the limestone, silica, alumina, oxides of iron, and magnesia, with some alkalis, and a small amount of titanic acid. As the alteration progresses, all these constituents continue to increase in amount. But in these later stages of the alteration the alumina, oxides of iron, and alkalis are added in relatively greater proportion than the other constituents, while no further addition of magnesia or lime takes place, the proportion of these constituents remaining essentially the same, the carbonic acid escaping and carrying the rest of the lime with it.

This means, speaking generally, that pyroxene, and some scapolite, were first developed in the limestone, and that later, feldspathic constituents increased in amount, the calcite present being removed in solution.

From the calculation of the norms given on page 107 it is seen that, speaking generally, Nos. 1 (b), and 2, have the following mineralogical composition:—

	No. 1 (b)	No. 2
Feldspathic constituents	48·57	67·35
Pyroxenic (iron magnesia) constituents	46·63	26·28
Iron ores	3·20	5·27
	98·40	98·90
Water	1·66	1·00
	100·06	99·90

During the change of No. 1 into No. 2, and this into No. 3, the information afforded by the analyses bears out that obtained from the study of the thin sections, showing that there has been a very considerable re-arrangement among the constituents of the rock, for instance, as shown by the fact that while the alumina and alkalis increase in No. 2 and No. 3, there is not a corresponding increase in the total amount of silica, the silica thus required to make additional feldspathic constituents being set free by some other reactions going forward in the rock.

It seems also that after the development of a certain percentage of silicates in the limestone, as shown in No. 1, during which process the carbonic acid was expelled, and the lime combined with it used in the production of new minerals, no further lime was fixed. In the earlier stage the waters given off by the granite, having accomplished the transference of material into the limestone, passed off with CO_2 in solution. In the later stages of the alteration, however, these waters, while continuing to deposit silicates in the limestone, made place for these latter by carrying off carbonate of lime in solution.

As will be seen, the difference in chemical composition between specimen 2 and specimen 3 is very small. The more highly altered rock, No. 3, is rather richer in iron, magnesia, and alkalis, while it is considerably poorer in lime, and contains less chlorine. These differences are seen to represent a slight increase in the proportion of hornblende and orthoclase present, and a decrease in the amount of plagioclase and scapolite in the rock.

If, for the purpose of comparing the composition of these alteration products with that of igneous rocks, the norms are calculated, these are found to be as follows. Since No. 3 is essentially the same as No. 2, the norm of the latter rock may be taken to represent both specimens, and with it is given the norm of the silicated portion of No. 1 (No. 1 (b).)

	No. 2	No. 1 (b)
Orthoclase	7·23	7·74
Albite	26·20	15·24
Anorthite	27·94	25·59
Nepheline	5·56	
Sodalite	0·42	
Diopside	19·78	34·81
Akermanite	..	6·97
Olivine	6·30	4·85
Calcite	0·20	
Ilmenite	1·52	1·40
Magnetite	3·71	1·80
Pyrite	0·04	
	98·90	98·40
Water	1·00	1·66
	99·90	100·06

In the quantitative classification the rocks, therefore, have the following position:—

No. 2		No. 1 (b)	
Class II	Dosalane	Class III	Salfemane
Order 5	Germanare	Order 5	Gallare
Rang 3	Andase	Rang 4	Auvergnase
Sub-rang 4	Andose	Sub-rang 4	Auvergnose

While, therefore, the quantitative classification is intended to apply only to igneous rocks, this final product of the metamorphism of the limestone, when compared with igneous rocks, readily takes its place as an andose, a group which includes many rocks which are commonly known as diorites, gabbros, basalts, diabases, and essexites.

For purposes of comparison, the analysis of this amphibolite (No. 2) is here repeated, together with the analyses of four true igneous rocks which have been produced by the solidification of molten magmas.

	I	II	III	IV	V
SiO_2	50·00	48·81	50·86	50·73	48·85
TiO_2	0·82	0·74		1·59	2·47
Al_2O_3	18·84	16·62	15·72	19·99	19·38
Fe_2O_3	2·57	1·17	9·77	3·20	4·29
FeO	5·51	7·47	2·48	4·66	4·94
MnO	0·08	0·12		0·05	0·19
CaO	10·65	10·30	10·52	8·55	7·98
MgO	4·63	8·28	3·55	3·48	2·00
K_2O	1·18	0·76	0·90	1·89	1·91
Na_2O	4·46	3·31	3·89	4·03	5·44
CO_2	0·10	0·55			
Cl	0·10	0·03			Not det.
S	0·03	0·06			
P_2O_5				0·81	1·23
H_2O	1·00	0·95	2·53	0·77	0·68
	99·97	99·17	100·22	100·13[1]	99·36

[1] Including BaO ·27

I. Amphibolite resulting from the alteration of limestone Maxwells crossing, lot 5, concession VI, township of Glamorgan, Ontario.

II. Dik cutting limestone, lot 27, concession VIII, township of Methuen, Ontario (see p. 159).

III. Gabbro, near Baptism river, Minnesota, U.S.A. (Wadsworth, Geol. Survey of Minn. 2, p. 79, 1887).

IV. Diorite Big Timber creek, Crazy mountain, Montana (Wolff, Bull. U.S.G.S. 148, p. 144, 1897).

V. Normal Essexite Mount Johnson, Quebec (Adams - Jour. of Geol., April May, 1903).

Even the silicated portion of the half-altered limestone (analysis I (b)), which in the quantitative classification would fall under Auvergnase, has certain igneous rocks which approach it rather closely in composition, although it is higher in lime than any igneous rock whose analysis has been hitherto recorded, as emphasized by the fact that akermanite appears as a standard mineral in its norm. The following igneous rocks resemble it most closely:

	I	II	III
SiO_2	48·11	46·15	46·16
Al_2O_3	16·98	13·57	13·86
Fe_2O_3	...	3·61	5·26
FeO	7·82	8·15	1·81
MnO	1 88		...
MgO	5·67	12·63	11·60
CaO	17·75	15·15	15·74
Na_2O	1·82	1·29	1·05
K_2O		...	0·30
H_2O	...	...	3·40
	100·03	100·55	99·18

I. Saussurite gabbro, Yttero, Norway.

II. Hypersthene gabbro, Ural, Russia (Loewinson Lessing G. Sh. Jushno Saos, Dorpat, 1900 p. 166).

III. Gabbro (not fresh), Laurion, Greece (R. Lepsus — Geol. v. Attika, Berlin, 1893, p. 98).

In connexion with this alteration it is co be noted that the change is not one of solution, or digestion of the limestone by the granite, for the fragments preserve their sharp and well defined forms, even when the alteration is complete.

The limestone, away from the granite, is a white crystalline marble, containing scarcely any impurities, and effervescing

freely in fragments with cold dilute hydrochloric acid, showing that it is an essentially pure carbonate of lime.

The granite of this batholith has not been analysed, but is in all probability of essentially the same composition as that of the adjacent Methuen batholith, the analysis of which has already been given.

The changes are the result of the transfusion into the limestone of certain constituents which are at present in the granite magma. A remarkable fact in connexion with the alteration is that the granite is an acid variety, containing a very small amount of biotite as its only bisilicate, and has, notwithstanding this fact, transfused into the limestone not only silica, alumina, and alkalis, which might be expected, but also large amounts of magnesia and iron. The limestone evidently fixed certain exhalations of the granite magma in relatively greater abundance than others, exerting a species of selective action. Many cases have been described in which the granite magma passed by differentiation into a gabbro, but here the granite retains its normal character up to the contact, and at the same time changes the limestone into a rock having the composition of a gabbro.

That similar changes are brought about by the action of acid magmas upon limestones elsewhere, is shown by two occurrences described by Kemp, and one by Lindgren.[1] The first is from San José, in the State of Tamaulipas, Mexico, the second from Morenci, Arizona, and the third from White Knob, Idaho. In all cases highly acid intrusive rocks, quartz porphyries, or quartz-diorite porphyries, very low in iron, penetrated limestones which are so pure that they can yield little or no garnet of themselves. In each case, the intrusives have developed in the limestones large amounts not only of an alumina garnet (grossularite), but also of an iron garnet (andradite), showing that the acid magma had transfused into the limestones large amounts of SiO_2, Al_2O_3, and Fe_2O_3, which the limestones had fixed in the form of garnet.

[1] Kemp, J. F.—Ore Deposits at the Contacts of Intrusive Rocks and Limestones and their significance as regards the general formation of veins. Economic Geology, vol. II. No. 1. 1907, p. 1.

Kemp, J. F. -Trans. Am. Inst. Mining Eng. vol. xxxvi. p. 192

Lindgren, W.—U.S. Geological Survey, Professional Paper No 43, p. 134.

Kemp's conclusions concerning these occurrences exactly coincide with those reached from a study of the occurrences in the Haliburton-Bancroft area, as shown by the following quotations from the paper referred to above:

"First of all the question may be raised as to whether the eruptive has melted into its substance sufficient limestone to yield the zones which have then crystallized out from fusion. This view is opposed both by the sharp contacts afforded by the eruptive against the garnet zones, by the variability of the zones in mineralogy, and by the fact that the necessary ingredients of andradite would not thereby be afforded. In almost all cases the eruptive is a highly acidic rock, a quartz porphyry, or quartz-diorite porphyry. The percentage in iron is very small, far below the requirements of the iron-lime garnet, and the general composition not at all adapted to yield the zones. On the contrary, we are irresistibly led to the conclusion that from the intrusive rock has come either highly heated water gas, or highly heated water itself, in the closing stages, and that one or both of these have brought to the limestone the silica, iron oxide, and alumina for the production of the lime-silicates. After the production of the garnet and its associates was well under way, they brought in also the copper and iron sulphides, which are the commonest ores.

The silica and the other dissolved materials did not wander farther from the eruptive, because the limestone promptly intercepted them, and locked them up in silicates; but undoubtedly carbonated water and carbon dioxide gas were yielded in great quantity, an inference which falls harmoniously in line with what we know of volcanic emissions."

These rocks will be referred to again in that section of the report dealing with amphibolites.

Farther to the east, along the same contact, on lot 19, and again on lot 15, on the line between concessions VI and VII, the pyroxene-scapolite gneiss is again well exposed and can be seen passing into the limestone. At the latter locality, however, a certain amount of epidote is present in large grains, growing in the scapolite.

In this connexion it may be mentioned that a pyroxene-scapolite gneiss, holding a considerable amount of microcline, and almost identical in character to those already described, but some-

what coarser in grain, is found in the adjacent township of Monmouth, forming a heavy band, which crosses Pine lake on lots 11 and 12, concession III. Here again it occurs flanking a band of crystalline limestone, and cut by great dikes of pegmatite, and is near the margin of a granite mass, in this case the Anstruther batholith. In this scapolite gneiss also there are little bands, layers, and strings of the crystalline limestone, which still survive, and all stages of the transition from one rock to another can be traced. The rock has a streaked or banded structure, the direction of which conforms to the general strike of the rocks of the district, and which is caused by the more or less perfectly parallel arrangement of the constituents. Under the microscope this Pine Lake rock is seen to be composed of pyroxene, hornblende, scapolite, microcline, sphene, tourmaline, epidote, and apatite. Pyroxene, scapolite, and microcline are the chief constituents. Hornblende is less abundant. The other constituents are accessory. No plagioclase, or quartz was present in the slides. All the constituents are identical in character with those described in the Glamorgan rock. In the thin sections also, the rock, although banded in character, is seen to possess the mosaic structure before referred to, the grains of pyroxene being often rounded in form, and none of the minerals, with the exception of some of the epidotes, having any approach to idiomorphic development.

On going north from Maxwells crossing, from the limestone band into the body of the Glamorgan batholith, on concessions X and XI of Glamorgan, by the road which runs to Bark lake, the granite is seen to break through the altered sedimentary series just described, and to be filled with inclusions of a dark basic rock, which inclusions, while more numerous in some places than in others, form, in that portion of the batholith traversed by the Bark Lake road, about one-half the whole mass. In the field, these inclusions present every evidence of being merely detached masses of the invaded rock which have been floated away in the moving granite magma, exactly as they are on the eastern section of this batholith on the Buckhorn road, as described above. They also are usually filled with little veins and strings of granitic material, which traverse them in all directions and generally have a somewhat harder, and, to use a term employed by the French geologists, a more granitized appearance than the amphibolite

above described; but they frequently occur in positions which leave practically no doubt that they are detached fragments of the rock in question.

Specimens from three of these inclusions were collected and examined under the microscope. The localities from which they were taken were as follows: lot 7, concession VIII; lot 6, concession VI, both on the Bark Lake road; and lot 12, concession VII, on the Burnt River road—all in the township of Glamorgan

They were found to be practically identical in mineralogical composition, although that from lot 6, concession VI, was much richer in iron-magnesia constituents. They are composed of hornblende, biotite, orthoclase, plagioclase, and quartz, with very subordinate amounts of apatite, sphene, and iron ore. The hornblende is identical in character with that found in the pyroxene-scapolite gneiss, and in the pyroxene-feldspar gneiss, but it is relatively more abundant. The biotite is usually less abundant than the hornblende. The orthoclase and plagioclase vary in relative amount. There is but little quartz present, and no calcite or scapolite was found in any of the specimens. The rocks present a foliated structure.

These inclusions thus closely resemble the more altered of the two varieties of amphibolite of which analyses are given on page 104. The pyroxene has disappeared, being displaced by hornblende, and biotite. The scapolite, if originally present, has been replaced by plagioclase, and the amount of potash, feldspar, and quartz has been increased. The rock from lot 6, concession VI, being very dark in colour, and consisting essentially of hornblende and plagioclase, is now a typical amphibolite, like that which occurs so commonly in the batholith elsewhere in this and other Laurentian areas. The other two rocks are relatively richer in feldspar, and thus lighter in colour, and contain more orthoclase, being thus intermediate in character between amphibolites and grey gneisses.[1]

In the southwest extension of this batholith, in the district about Gelert, and over the southern boundary of Haliburton township to Kinmount, grey gneiss, in many places closely resembling the amphibolite, forms the surface of the batholith, and is cut through by much granite, gneiss, and pegmatite. This

[1] See L. C. Gratton.—On the Petrographical Relations of the Laurentian Limestones and the Granite in the Township of Glamorgan, Haliburton county, Ontario. Can. Rec. of Sci., January, 1903. (vol. ix, No. 1.)

grey gneiss, somewhat less granitized than usual, is, at Gelert, interbanded with the limestones, of which there is a small exposure in a cutting where the Haliburton [illegible] railway crosses the Gelert road. It seems, therefore, that in this southerly extension where the batholith becomes narrower, the exposures represent a more superficial portion of the intrusion in which the contact rocks are relatively more abundant.

In a very few cases, in other [illegible] area embraced by this report, fragments of white [illegible] limestone, or marble, coarse in grain, but not otherwise [illegible] found enclosed in the granite. Such occurrences [illegible] extremely rare, so much so that they may be said [illegible] to the general statement, that when the granite [illegible] limes[illegible] not found to contain inclusions of the [illegible] where such inclusions are best seen is along [illegible] west arms of the southern portion of Kasshabog lake in the [illegible] of Methuen. The western portion of this extension is known [illegible] Lake bay. The gneissic granite area about this lake contains, as a general rule, very few inclusions, but along these arms of the lake there is a part of the batholith in the form of a belt, about half a mile wide which is filled with inclusions. These inclusions are seen in the granite in the little islands in the lake, as well as on the rocky shores on either side, the course of the belt coinciding with the strike of the foliation of the rock. This fragment-filled belt of granite evidently marks the line of a great elongated body of the invaded rock, which had settled down into the granite from above and was undergoing disintegration when the granite solidified. The great majority of these inclusions are amphibolite, like that bounding this granite mass on the north, but on the north shore of the lake, on lot 9, concession IX, and again in two places on lot 8, concession VI, blocks of white crystalline limestone (such as those which occur interstratified with the amphibolite elsewhere in the district) are found embedded in the granite. The inclusion at the first mentioned locality is about 30 feet thick, and while very coarse in grain is pure, containing scarcely any admixture of silicates. It is flanked on one side by the waters of the lake, and on the other by a band of the rusty sedimentary gneiss which is usually found interstratified with it. Then comes the granite, which near the contact is rather more basic than usual, but is of the normal type a few yards away. The inclusion on the

east side of lot 8, concession VII, is a block, 60 feet long and 6 feet wide, bounded by the waters of the lake on one side, but coming directly against the granite on the other. The contact is sharp, and neither rock presents any evidence of being influenced by the other.

While these occurrences are very interesting, they are, as has been mentioned, very unusual, the almost universal rule being that the limestone near the contact is filled with various silicates which have been developed in it, while the inclusions actually present in the granite near the contact are composed of amphibolite, or of some allied rock.

As there are wide brecciated zones about the granite-gneiss batholiths in several parts of this area, and as the granite-gneiss itself contains almost everywhere great numbers of inclusions, the question naturally presents itself: Has the granite-gneiss anywhere actually dissolved the invaded rock? Several occurrences are worthy of note in this connexion.

By the side of the road running west from Gooderham, on the south side of the Glamorgan batholith along the line of contact to which reference has already been made, on lot 19 on the line between concessions VI and VII of the township of Glamorgan, there are large exposures of the granite, which in some places has a coarse pegmatitic development, but which elsewhere passes into fine-grained varieties, with irregular bands and streaks of darker basic rocks, the whole having a pseudo-stratified character. In adjacent exposures the mass becomes much less distinctly stratiform, and the basic rocks become very irregular in character and shape. In some places they are represented by streaks and lumps of dark green malacolite, holding bunches of molybdenite an inch across. This rock frays away into another, which swarms all through it in the form of little arms and strings, and which is composed essentially of pale green pyroxene and scapolite, the relative proportions of the two minerals varying very considerably, but the latter being the more abundant of the two. This rock resembles the scapolite gneisses or amphibolites about Maxwells crossing, but in its turn seems to pass into the fine-grained, quartz-bearing pegmatite, the whole having an irregular streaked structure in the direction of the general strike of the country rock. In other exposures the green malacolite bands pass into a rock composed of quartz, feldspar, and pyroxene, through which can be found

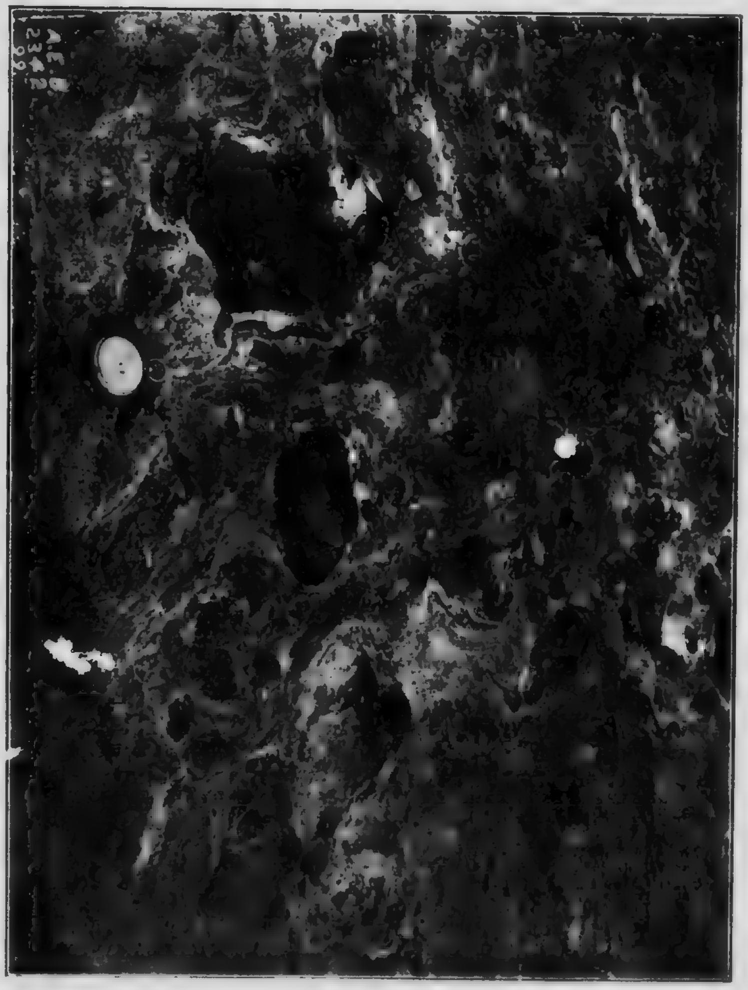
small scattered masses of the adjacent crystalline limestone, containing scales of biotite, and crystals of pyroxene. In these cases it would seem that a partial solution of the limestone in the granite had taken place, after the former had been first altered to a malacolite rock, or to a rock composed of malacolite and scapolite, that is to say, into a rock having the composition of a pyroxene-scapolite gneiss.

A second occurrence is on the southern extension of Kasshabog lake, in the township of Methuen, at the locality before mentioned. Here the banded amphibolite is invaded by the granite-gneiss, which has broken it into fragments, and partially dissolved some of them, giving rise to a greyish, streaky looking mass of irregular composition, much lighter in colour than the amphibolite, and darker than the granite, being grey instead of reddish. Three stages of this process are shown in the photographs (See Plates XVII, XVIII, and XIX). While the amphibolite is composed of hornblende and a feldspar which is frequently twinned polysynthetically, and is probably plagioclase, with a very small percentage of sphene and iron ore, the structure being the mosaic structure usually found in these rocks, the greyish rock is seen under the microscope to be biotite-gneiss, which contains, in addition to a large amount of biotite, both quartz and feldspar, the latter probably being in part orthoclase and in part plagioclase; so that the grey rock has a composition intermediate between that of the amphibolite and the granite. It possesses, moreover, a typical gneissic structure, the foliation or flow structure being very well marked.

This rock of intermediate character, as well as the granite itself, can be seen to have been forced into fissures in the amphibolite, and thus to have further broken up the original blocks of this rock, probably having lost, however, in great part at least, its solvent power, owing to the fact that it already held some of the amphibolite in solution. These fragments were then carried away with a rolling movement in the pasty flowing mass, so that frequently the banding of the amphibolite fails altogether to coincide in direction with the direction of the fluidal foliation of the streaky mass in which it is enveloped. Fresh granitic material, often coarsely crystalline, cuts through the mixed mass described above, and the final stage of the process consisted in the intrusion of well defined veins of pegmatite, usually less than a foot in dia-

Solution of amphibolite in granite (first stage). Kasshabog lake, township of Methuen, lot 9, concession VIII.

Solution of amphibolite in granite (second stage) Kasshabog lake, township of Methuen, lot 9, concession VIII



Solution of amphibolite in granite (third stage). Kasshabog lake township of Methuen, lot 9, concession VIII.

meter, composed of quartz and orthoclase, with occasionally black tourmaline, which cuts across the whole. The foliation of the gneiss was not produced by later dynamic action, for pegmatite veins show no signs of crushing.

Furthermore, at the extreme easterly end of the long extension of Kasshabog lake above mentioned, and in the country immediately to the east of this, on the road where the granite runs into a corner between two tongues of amphibolite, a basic development of the granite is seen, also due, in all probability, to a partial solution of the invaded amphibolite.

Other examples of the same phenomenon, but on a larger scale, may be seen at many places about the margin of the Anstruther batholith. At the northern end of this occurrence, where the granite-gneiss, of the batholith runs up into the township of Monmouth, it is bounded on the north by an extension of what has been referred to as the Catchecoma gneiss. This is a basic rock which resembles in appearance a light coloured amphibolite, but the junction of the two rocks cannot be fixed. To the north of the Catchecoma gneiss is a dark coloured amphibolite, and then a band of limestone. The granite-gneiss, elsewhere red, becomes grey in colour, and poor in quartz as this northern boundary is approached, and passes into the Catchecoma gneiss, which is at first seen to hold a few pear-shaped inclusions of the amphibolite, which become more and more numerous as the contact is approached, where the amphibolite is reached, through which there run streaks of the invading rock. The amphibolite has evidently been partially dissolved by the granite magma, and the Catchecoma gneiss here consists apparently of the granite magma, rendered basic by the solution of amphibolite in it. There is no evidence of magmatic differentiation.

About a quarter of a mile from the margin of the normal amphibolite band, the granite resumes its normal character, and scarcely an inclusion can be found. In the Bancroft sheet accompanying this report, the boundary of the granite-gneiss as given, shows the limit of this rock in its normal development, the zone of solution being represented as a portion of the Catchecoma-gneiss.

Farther to the east, on the border of the same granite batholith where it crosses concessions XV and XVI of Anstruther, it also has a basic peripheral development; while on the western side, this northern intermediate zone passes

into a belt of grey gneissic rock, which continues down the whole length of the west side to the line of Harvey. This gneissic rock is grey in colour, and has a peculiar character quite different from that of the granite. It was found impossible to get actual proof that the whole of this great body of rock had been formed by the solution of the associated limestones in the granite magma. The field relations, however, in many respects favour this view. If such be the case, the solution must have taken place during the early stages of the intrusion, and after its formation this Catchecoma gneiss must have been disrupted by the rise of additional granitic material, or by later movements, for isolated fragments of it, as shown by the map, lie scattered about in the granite at the constricted portion of the batholith, in the district about the lakes in southern Anstruther and the adjacent parts of Cavendish. This gneiss will, however, be again referred to, and a description of it given in the section of the report dealing with the gneisses, produced by the alteration of sedimentary material.

Again, on the north shore of Big Cedar lake, on the east side of the same batholith, in concessions III and IV of the township of Burleigh, the contact relations of the granite-gneiss are strikingly shown. The granite-gneiss here is bounded by the great development of limestone in the southern part of Burleigh. This limestone, as shown on the Bancroft sheet, has a number of belts of amphibolite running parallel to its strike. On the north shore of Big Cedar lake, on its eastern half, the limestone is developed as an almost pure, coarse grey marble. About the middle of the lake, on approaching the granite, the limestone is found to be traversed by a great many masses of fine and coarse-grained pegmatite, while just at the contact with the body of the intrusion one of the amphibolite bands appears. This is dark in colour and looks like a sheared gabbro. It is a narrow band, and is also much penetrated by pegmatite. Beyond this, and extending to the western margin of the lake, is a belt of granite containing about one-half its volume of amphibolite inclusions. Beyond this, to the west of the lake, the inclusions become less numerous, and the granite-gneiss, showing a distinctly gneissic structure, forms a succession of great bare reddish roches moutonnées, extending into the central part of the township. As will be seen by the map, the mixed zone has

a width here of half a mile. Among the fragments in this mixed zone, referred to above as amphibolite, there are some which are dark in colour, and, so far as can be seen with the unaided eye, contain no quartz. These may be properly referred to as amphibolite. There are others, however, which are lighter in colour and hold more quartz, and there are also greyish streaks in the reddish gneiss. A study of great stretches of the bare glaciated surfaces shows that, while many of the inclusions consist of fragments of amphibolite—in some cases intact, and in others more or less squeezed out and elongated—there has been a considerable admixture of the two rocks, due to a solution of the invaded rock by the granite; basic streaks or *schlieren* having thus been formed in the latter. There has not, however, here been any wholesale solution of the amphibolite with the production of a zone of basic rock of intermediate composition, but each fragment seems to have been separately softened, penetrated, and partially dissolved, thus giving rise to *schlieren* in the viscous mass. The process of solution is in fact not complete, and many fragments show little signs of being affected.

Farther north, on the same side of the batholith at the eastern extremity of Crab lake, in the southern part of Anstruther, the granite—here developed as a coarse pegmatite—holds shreds and patches of amphibolite, and altered gneissic rocks, with, in one place, some few inclusions of highly altered limestone, apparently in the act of being dissolved; while to the south of Big Cedar lake, on the north shore of Stony lake, from the western limit of the Bancroft sheet, near Buckhorn, to Burleigh Falls, the same association of rocks is seen. Along this stretch of shore the red quartzose gneiss preponderates. With it are associated grey gneissic rocks, and masses of amphibolite, which are seen to be in the act of being broken apart or pulled out into streaks. These are more abundant toward Burleigh Falls. The whole occurrence presents in a most vivid manner the picture of a moving magma of diverse composition, the diversity resulting from the inclusion of the amphibolite masses, and in part also from the more or less complete granitization, or solution of some of them.

Another case where there had been, to a certain extent, a solution of limestone in the granitic magma, was observed on the south side of the road, on lot 10, on the line between concessions V and VI of the township of Dysart. This point is situated near

the edge of a limestone band. The granite-gneiss of the northern area passes beneath the limestone, and breaks up through it in numerous bosses of varying size, and also as dikes. The limestone is, as a result of this proximity of the granite on all sides, extremely altered, being filled with rounded grains of pyroxene, scapolite, sphene, and microcline. The rock is thus in the stage of transition into a pyroxene-scapolite gneiss. The dikes of granite (usually pegmatitic in development) which traverse the limestone, while in some cases presenting the normal character, in many cases are seen to have a dark coloured selvage on either side, and in other cases dark coloured streaks through the granite. These resemble strongly in appearance certain varieties of amphibolite, but have a slightly reddish tinge.

Under the microscope this dark coloured rock is found to be very poor in quartz, the silica of the magma having united with lime, and other bases, to produce pyroxene and biotite, which, together with microcline, and a certain amount of sphene, constitute the rock, which is a pyroxene-mica syenite. It seems practically certain here that after the limestone had been very much altered by exhalations from the magma, a portion of it was actually dissolved in the pegmatite magma, which, when it has solidified in its pure condition, is found to consist of microcline and quartz.

ORIGIN OF THE AMPHIBOLITE INCLUSIONS AND GREY GNEISS.

The origin of the inclusions of amphibolite, which have been described at some length, and which, as has been mentioned, are found more or less abundantly in almost every body of granite or granite-gneiss in the area, is not only a question of much interest, but one of much importance to the true understanding of the geological processes which have been at work in this region.

As is well known, similar inclusions of dark basic rocks, of the nature of amphibolite, are found in very many occurrences of granite, especially those of Archaean age, in various other parts of the world, and have been the subject of much investigation and widespread discussion. By many geologists they have been considered to be basic differentiation products from the acid magma, while others have looked upon them as fragments of foreign

rocks caught up by the granite.[1] In the region at present under discussion there are three ways in which it would be possible to consider them as having originated:—

I. As basic differentiation products ("ausscheidungen") from the granite magma.

II. Portions of the rock forming the walls or roof of the batholith, which had fallen into the granite magma and had partaken of its subsequent movements.

III. Fragments of intrusive masses, dikes, stocks, etc., which, if the granite be supposed to represent the original sub-crust in a softened or remelted condition, cut through this crust and were connected with basic effusives at the surface. These masses having been torn to pieces by the subsequent movements of the softened granite now appear as scattered fragments.

A careful study of all parts of the area has failed to furnish any distinct evidence that No. I is the true explanation anywhere. There is positive proof that No. II is the correct and only explanation of the inclusions in several parts of the area, as has been shown, and it is an explanation not opposed to the facts in any part of the area. The inclusions in some places, more especially in the great northern granite-gneiss areas, may have originated in part as set forth in No. III. The form of the inclusions sometimes suggests this, but the movements in the granite have been so great, and the inclusions have been so torn to pieces, that it is impossible to decide whether any of them have been derived from the source indicated under this head. The inclusions, consisting as they do, of amphibolite, or more rarely of peculiar varieties of gneiss, and occasionally of limestone, can be seen around the margins of the batholiths, in many places, to be fragments of the country rock, which has been shattered by the intrusion of the granite, and thus to be true inclusions—and not differentiation products "ausscheidungen" from the granite itself;

[1] Smyth, C. H., Jr.—Report on the Crystalline Rocks of St. Lawrence co., N.Y., 15th Ann. Rep. of the State Geologist, p. 490. The black inclusions in the granite-gneiss of the Adirondacks are considered to be broken masses of an older rock caught up by the granite-gneiss when the latter was still in a molten condition.

Frosterus, B.—Bergbyggnaden bi Sydröstra Finland, Helsingfors, 1902, p. 157. The amphibolites which are characteristic associates of the granite gneiss of southern Finland are probably for the most part altered dike rocks. Some of them still show a gabbro-like structure.

and there is no reason to believe from the form or composition of the inclusions elsewhere in the area, that they are ever due to magmatic segregation.

The occurrences which at first sight seem to militate against this second hypothesis are furnished by the limestones where these are invaded or penetrated by the granite batholiths. In such instances the detached fragments are almost altogether made up of amphibolite or pyroxene gneiss, and only very rarely of the limestone. The full explanation of such a seeming anomaly has already been furnished, showing that many of these amphibolite inclusions are in reality greatly metamorphosed fragments of the adjacent or overlying limestones. The amphibolite inclusions, therefore, originate in part from limestones, and are in part fragments of the amphibolite, which are interstratified with the limestones forming the country rock. The amphibolites from these two sources resemble each other so closely that it is in most cases impossible to tell them apart. The primary origin of the amphibolite constituting the inclusions of the last mentioned class need not be dealt with here, as it is considered in the section where these rocks are described; but it may be stated that the rock, in some cases, was derived from the deformation of basic igneous intrusions, in other cases probably from basic pyroclastic sediments; while still others may have resulted from the alteration of normal sedimentary rocks of a certain character.

The further question as to how far granite, having caught up inclusions of the rock through which it breaks, in the manner described, dissolves, digests, or further acts upon them, is one upon which it is more difficult to get conclusive evidence. That it does so in some cases is certain, as, for instance, in the occurrences about Kasshabog lake, in the Methuen batholith, and at the various places on the margin of the Anstruther batholith, and elsewhere, which have been described on page 116. But these products of solution bear a marked resemblance to much of the grey gneiss, which has been described as so widely distributed through the great northern area of the granite-gneiss. In several cases also in these northern parts of the sheet there was evidence that the grey gneiss had a definite genetic connexion with the amphibolite; as for instance, along the shore of Rock lake, in the township of Livingstone, where there are, in the prevailing

red gneiss, narrow bands, greyish in colour, and which weather more readily than the red gneiss. The amphibolite, which also occurs in the same exposures, is very much darker in colour, nearly black. In many other cases, however, there seems to be a transition from the undoubted amphibolite inclusions into the narrow bands of grey gneiss. When examined under the microscope these narrow bands are seen to contain much more biotite than the gneiss, as well as certain decomposition products, probably representing rhombic pyroxenes. A little quartz is also present, and the majority of the feldspar grains are untwinned.

It is certain that in many places these streaks of grey gneiss represent inclusions of the amphibolite impregnated with gneissic material, and in a manner dissolved in the red gneiss. If the whole body of grey gneiss associated with the red gneiss in most parts of the area where this latter rock occurs has originated in the same way, this process of solution must have gone on very extensively. The red gneiss, in most cases, however, has exerted no solvent action on the amphibolite, as shown by the fact that the fragments of the latter rock enclosed in it are sharp and angular, or when softened and pulled out retain sharp and well marked boundaries. In view of this fact, and bearing [illegible] the grey gneiss is much more uniform in character [illegible] be looked for under such circumstances, very strong evidence should be forthcoming before concluding that all the grey gneiss in the area is a product of the solution of amphibolite fragments in the red gneiss. Undisputed evidence of solution on such an extended scale has not, moreover, as yet been obtained.

While it is possible in many parts of the area to prove that the limestones themselves have been more or less completely altered by the granitic batholiths, as well as to determine the proclasses of alteration, and the nature of the resulting products, in other places a series of very interesting rocks are found associated with the limestones, the origin of which cannot always be determined with certainty. Comparative studies in various parts of the area, however, where rocks of these classes are found in various stages of alteration, has made it possible, in many, if not in most cases, to determine with a high degree of probability the original character of the occurrence.

Thus, in the southern portion of the township of Dudley, there is an outlying portion of the calcareous series, completely

isolated in the igneous gneiss of the great northern batholith. This area is pear-shaped, being six miles in length, with an average width of about two miles, and embraces Lake Kennibik, and Lake Miskwabi. The series composing it lies nearly flat, dipping for the most part at low angles to the east and south, the strike following the curving outline of the area. This flat-lying attitude is shared by the foliation of the igneous gneisses surrounding the area. The limestone series evidently lies upon the gneiss just mentioned, in the form of a thin plate, or layer. Under these conditions a very intense alteration would naturally be looked for in the sedimentary mass in question.

On the eastern side of Lake Kennibik a development of the labradorite rock already described occurs. The rest of the area is occupied by the limestone series, through which, in several places, the underlying igneous gneiss protrudes. This is especially the case on the northwest shore of Lake Miskwabi, where the gneiss and the altered series occur in intimate admixture.

The sedimentary series consists of beds of highly crystalline limestone, interstratified with beds of light coloured and more or less rusty weathering gneissic rocks, and occasionally with others of dark coloured amphibolite. The limestones are, in some places, comparatively pure, but they usually contain, more or less abundantly, grains of various silicates developed in them by metamorphic processes. These in some cases, become so abundant that they almost entirely replace the original calcite. Thus on lot 20, concession III of Dudley, the limestone has been converted into a uniform, medium-grained aggregate of calcite, serpentine, and phlogopite, with a few scales of graphite. Only about 20 per cent of calcite remains. The uniform character of the rock is occasionally interrupted by the segregation of mica in nests or bunches of small, light brown scales, these nests being sometimes as much as an inch in diameter

Under the microscope the light brown phlogopite individuals look perfectly colourless, and are frequently curved into a scimitar-like shape, or are opened up along the cleavages, the spaces so produced being filled with calcite, indicating that movements took place in the rock during its alteration. The serpentine grains also hold inclusions of calcite and phlogopite, and although it contains no cores of the mineral from which it has been derived, this mineral undoubtedly represents an altered

pyroxene, as cores of this mineral are found in the serpentine in the immediate vicinity.

With these limestones the light coloured gneissic rocks, as above mentioned, occur as interstratified bands. These are well seen at the extreme east end of Lake Miskwabi, on the line between lots 21 and 22, concession III of Dudley. In the field there seem to be two varieties of this gneiss, but when examined in thin sections the rocks are seen to be practically identical in character.

The rock is of medium coarseness of grain, and is distinctly foliated, the foliation in some cases being marked by little leaves of quartz, and in others by mica. It differs distinctly in appearance from the igneous gneiss of the batholiths, being grey in colour, and not pink or red. The rock is composed essentially of quartz and feldspar. The feldspar is chiefly a microcline, but a large amount of plagioclase is also present. The quartz leaves show a somewhat uneven extinction. The only other minerals present are biotite, sphene, and zircon, all of them in very small amount. The mica is a deep brown biotite. No distinct evidence of cataclastic structure can be observed. The somewhat rusty weathering is due to the presence of a very small amount of pyrite, which is not seen in the slides in question.

A somewhat similar rock occurs interstratified with the pure limestone farther west on the south shore of the same lake, on lot 20, concession III of Dudley. This rock is somewhat coarser in grain, but has a distinct foliation as before. It is also composed chiefly of feldspar. This, however, is all microcline. Quartz is present in leaf-like form, with sphene, graphite, and pyrrhotite as accessory constituents. The first mentioned mineral occurs in elongated, more or less rounded grains, of a pale brownish colour, while the graphite is present in the form of a few minute shreds, and the pyrrhotite in rather large irregular-shaped grains, whose decomposition gives rise to the rusty surface of the weathered rock. This rock, however, differs from that just described, in the presence of a considerable amount of pale green pyroxene, in rather large irregular-shaped grains. The rock also shows a distinct granulation (cataclastic or protoclastic structure), the feldspar occurring in the form of augen, surrounded by smaller grains of the same mineral. It may be termed a pyroxene-bearing augen gneiss. On Lake Kennibik also, gneisses hav-

ing a general similarity of appearance to these are found, associated with the limestone in the same manner. One of these occurs on lot 23, concession VI of Dudley. It is found interstratified with the limestones in the form of thin bands, the rocks having a very low southeast dip, and being thrown into a series of small folds, each only a few feet in width. It is nearly white on a fresh fracture, and has a distinct foliation, and weathers somewhat rusty. Under the microscope it is seen to be composed of orthoclase, plagioclase, quartz, and a pale green pyroxene, with a considerable amount of calcite, and a few grains of sphene. The plagioclase is less abundant than the orthoclase, and the two minerals, in places, show a tendency to perthitic intergrowth. The pyroxene often shows skeleton forms, while the calcite occurs in large grains of somewhat irregular outline, neither penetrating nor penetrated by the other minerals of the rock. None of the constituents have even an approximate idiomorphic development. There is no evidence of cataclastic or protoclastic action, and no augen structure.

A finer grained pyroxene gneiss also occurs on the adjacent lot, number 24, concession VI of Dudley. This is similar to the one just described, but is finer in grain. It is composed of orthoclase and plagioclase, in about equal amounts, which together make up a very large proportion of the rock. With these is associated a considerable amount of a very pale greenish pyroxene. There is also present a small amount of biotite, concentrated in some layers, as well as a certain amount of sphene, and pyrite, and a very small amount of quartz, with a few shreds of graphite.

Of these four occurrences it is probable that the first two represent sheets of the igneous gneiss of the batholith in a highly sheared or granulated condition, while the latter two have the appearance and general character of extremely altered sediments. A fuller description need not be given here, as it will be found in the sections treating of the sedimentary gneiss.

Of the amphibolite associated with the limestone, a specimen from lot 19, concession III, was examined. The rock is very dark in colour, owing to the preponderance of the iron-magnesia constituents, and possesses not only a distinct foliation, but also an indistinct banded character parallel to this, due to the variation in the relative proportions of the constituent minerals in the different bands. Under the microscope it was found to be free

from feldspar, and to be composed of hornblende, pale green pyroxene, and scapolite, with biotite, and sphene, as accessory constituents. It is thus identical with certain of the amphibolites resulting from the alteration of limestones, described from Maxwells crossing, in the township of Glamorgan, and elsewhere.

In this Dudley area, therefore, we have an isolated remnant of the limestone (Grenville) series lying in (or floating upon) the igneous mass of the great northern batholith. It consists chiefly of sedimentary material, in the form of extremely altered limestones, associated with siliceous bands now changed to fine grained pyroxene gneisses. With this, however, there is associated masses and dikes of the igneous gneiss intruded from below, and also thinner bands and layers of the same gneiss, much sheared and granulated; and probably, in some cases, somewhat altered in composition by the solution of a certain amount of limestone, as indicated by the development of pyroxene in it.

THE NODULAR GRANITE OF PINE LAKE, TOWNSHIP OF CARDIFF

A granitic mass of peculiar character, and differing in many respects from any other which is found in the area, occurs in the southern portion of the township of Cardiff, and stretches south into Chandos, extending about half way across the township[1]. The mass forks toward the south, and is 5½ miles long, and 3 miles wide at its widest part. It is excellently exposed on the rocky shores of Pine lake, which consist of the granite, except at the northern and near the southern end of the lake, where this rock is associated with a dark gabbro-like amphibolite, through which it apparently cuts.

The granite is rather fine in grain, reddish in colour, and in many places is quite massive. It usually, however, shows a somewhat gneissic structure, marked chiefly by the presence of small and ill defined but rudely parallel streaks, differing from one another somewhat in size of grain. Where this gneissic structure is seen, it coincides in direction with the strike of the associated amphibolitic rock, which in places is also foliated. Much of the granite resembles aplite in appearance, but in places it passes into a coarse pegmatitic development, holding large masses of black schorl. Its general character, except for these minor variations,

[1]See Bulletin Geol. Soc. of America, vol. 9, p. 163, 1898.

is uniform over a very considerable tract of country, and its appearance is that of an undoubted igneous intrusion.

The granite, in places, contains peculiar nodules, which are of much interest on account of the light which they throw on certain processes which were at work in the cooling magma. These nodules do not occur throughout the whole mass of the granite, but are confined to a portion of it, which, although situated toward the northern limit, is from 200 to 300 yards from its contact with the amphibolite, so that the nodular development cannot be regarded as a contact phenomenon. Along the contact, the granite is in fact free from nodules. The localities where the nodules have been found are all situated on concession III of the township of Cardiff, being chiefly on lots 13 and 15, which lie opposite to one another on the north and south sides of Pine lake, respectively. They are also found to the northeast of the lake, at a point probably about lot 18 of the same concession. In these localities the nodules are abundantly disseminated through the rock, although not thickly crowded together as in many other similar occurrences elsewhere described. Where most abundant, two hundred were counted on a surface of 36 square feet. Elsewhere they are much less numerous.

They are usually spherical in form, but in some places have a more or less flattened or elliptical outline. This is more especially the case where the granite shows a tendency to foliation, the longer axes of the nodules in this case being parallel to the strike of the rock. The nodules have a diameter of from 1 to 8 inches, but usually measure from 2 to 3 inches across, and can readily be broken out of the rock, entire and almost free from the surrounding matrix. Those which have been cut across and smoothed by the glaciation of the country show the inner portion of the nodule to be lighter in colour than the normal granite.

Being harder and more resistant than the granite, furthermore, they stand out a little from its somewhat disintegrated surface. Many of the nodules, when thus ground flat by the action of the ice, also exhibit a more or less zonal structure, the central portion being somewhat different in composition from the exterior, although this is not always seen. There is, moreover, usually a little sponge-like mass of black tourmaline near the centre, while large glistening poikilitic plates of muscovite are often seen

Although throughout the greater part of the area in which they occur these nodules are scattered through the rock without any definite arrangement, in one or two places they were found arranged in rows. The nodules in such rows vary somewhat in diameter, though not greatly, and are at first separated by an interval of 2 or 3 inches. On following along the line, however, they are found to come closer together, and then to form a continuous string, touching one another, the long row of contiguous balls being here and there interrupted by spaces of the normal granite. Still further on, as indicated in Fig. E.

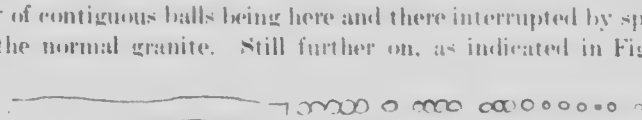


Fig. E. Pine Lake granite. Vein passing into separate nodules. One-fiftieth natural size.

the nodules of the row are found to fuse or coalesce, at first into a series of sausage-like masses, and then into a continuous band having the width of a single nodule, a band which, as exposed on the glaciated surface of the rock, no observer would hesitate to regard as a true vein filling a fissure, could not its passage into the separate nodules be distinctly traced. These veins, moreover, in some cases show a rude banding parallel to the walls, for the concentric structure of the nodules passes naturally over into the banded structure of the vein. The quartz, which is more abundant in the outer portion of the nodules, is thus more abundant on the sides of the vein, while muscovite and feldspar, being more abundant toward the centre of the nodules, are also more abundant toward the middle of the vein. The relation of the vein to the series of spherical masses, moreover, is indicated by the successive little sponge-like bunches of tourmaline, (see Fig. F) rounded in general outline, like those found toward the cen-

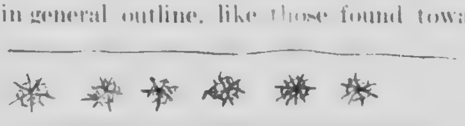


Fig. F. Pine Lake granite. Sponge-like bunches of tourmaline arranged at intervals along a vein. One-fifth natural size.

tral part of the nodules, which are distributed along the length of the vein at more or less regular intervals. In some cases even traces of the medial line can be seen on the weathered surface, passing down the length of the vein, and suggesting the meet-

ing place of the combs in the combed vein. These veins are well defined against the granite, although the boundary is not absolutely sharp, and occasionally they split and fork as other veins do, and pass into a row of nodules. Their continuity in depth could not be so well studied, as they are exposed chiefly on horizontal surfaces. In one instance, however, on the face of a little cliff, one of them could be seen to extend vertically through the granite in a direction at right angles to its strike, for a distance of three feet, and then downwards out of sight. It is certain from this and numerous other observations, that these veins do not represent merely single lines of nodules, but rather sheets which fray out into separate nodules along their outer margins. (See Plate XX, Figs. 1, 2, and 3.)

Whether irregularly disseminated through the rock, as is usually the case, or arranged in lines or sheets, as in certain rare instances, the nodules bear a striking resemblance, so far as mode of occurrence is concerned, to the spherulites, axiolites, and other similar structures seen in obsidian and other volcanic rocks, although, of course, on a very much larger scale.

The several structures described can be duplicated on a small scale in many hand specimens of the obsidian from the Yellowstone Park. The presence of tourmaline and muscovite is suggestive of the presence of mineralizers, which also play so important a part in the formation of spherulites. These nodules, however, differ in a marked manner from such spherulites, in that their composition is not identical with that of the enclosing rock, while in the case of the spherulites there is a practical identity in this respect. That an abundance of mineralizer was present in certain parts of the granite magma is, however, indicated by the streaks, or more or less irregular segregations of coarsely crystalline quartz and tourmaline found in places through the rock.

The red granite from various parts of the mass is found, when examined under the microscope, to be uniform in composition and microscopical character, although, as has been mentioned, varying somewhat in grain. Orthoclase and microcline preponderate largely, the former in untwinned grains, showing good cleavages, the latter presenting a well marked, cross-hatched structure. Soda-lime feldspars are also present, although in very subordinate amount. The microcline, which is usually

PLATE XX

Fig. 1.—Separate nodules and a vein.

Fig. 2. Lenticular nodules arranged in rows.

Fig. 3.—Separate nodules and forked vein like mass

Nodular granite from Pine lake, Ont

about equal to the orthoclase in amount, is, in some places, present in large grains, with irregular boundaries and a marked poikilitic structure, the enclosed grains consisting of orthoclase, plagioclase, and quartz, with a few individuals of biotite, and iron ore. These inclusions, which are often very numerous, are more or less rounded in form, their outline being often nearly circular. They are also quite irregularly oriented. The microcline in these cases is evidently younger than the other constituents of the rock, with the possible exception of the quartz, as has been found to be the case with this mineral in a number of granites which have been recently studied.

The quartz is much less abundant than the feldspar, and often occurs in sub-polygonal, or more or less rounded grains, instead of occupying the interstices between the other minerals as in a normal granite, a mode of occurrence which marks an approach in character to that seen in the granite porphyries. Highly pleochroic biotite is present in considerable amount, in the usual lath-shaped forms. A small amount of muscovite, often intimately associated or intergrown with the biotite, is also present. This mineral also occurs enclosed in the feldspars, either as well defined individuals, or in grains having the peculiar feathery, fretted, or lace-like margins exhibited by it in certain other granites; and in such cases it often has an edging of quartz surrounding a portion of it. In some cases it was even observed enclosed in quartz. A few grains of iron ore, and apatite, complete the list of minerals found in the rock.

Six nodules were selected for microscopical study, and eight sections, each comprising a whole nodule, were prepared. Three of these nodules, when cut across, showed a rather distinct concentric structure, the outer and inner portions differing somewhat in colour, the former consisting chiefly of quartz and sillimanite, and the latter chiefly of quartz, and muscovite. The outer and inner portions, however, are not separated by a sharp line, but fade into one another, so that no satisfactory separation of them for purposes of chemical analysis could be effected. Many nodules also, as has been mentioned, when broken across, show a small sponge-like mass of black tourmaline toward the centre. In the case of the other three nodules this zonal arrangement was merely suggested, the nodules being essentially uniform throughout. One of them, however, contained the tourmaline sponge

before referred to, near the centre, and in two of them there was an indistinct tendency to a radial arrangement on the part of some of the constituents.

The absence of pronounced concentric or radial structure is one feature in which these nodules differ in a marked manner from the basic concretions, nodules, and varioles described in other granitic rocks. On passing from the granite to the nodule there is seen under the microscope to be an abrupt change both in grain and composition. The regular mosaic of the granite is replaced a coarser grained, and sometimes indistinctly radial or sh ke arrangement of the constituents; the biotite and microcline disappear entirely, while the quartz and muscovite, especially the former, become more abundant, and sillimanite makes its appearance, usually in large amount.

Quartz, muscovite, and sillimanite are the chief constituents f the nodules. Plagioclase, and an untwinned feldspar, probably orthoclase, which are present in some nodules in considerable amount, but in others in very small quantity, with tourmaline, in some cases, and a few grains of iron ore and pyrite, complete the list of constituent minerals.

The quartz is uniaxial, and forms a well defined mosaic of polygonal grains, showing little or nothing of the tendency to develop rounded individu ls shown in the granite itself. It often holds an abundance of sillimanite needles, although in it this mineral does not usually occur in such mats as in the feldspar. It frequently contains lines of minute cavities, some of which enclose moving bubbles. The muscovite occurs in large colourless plates, often of very irregular outline, extending in some cases completely across the central portion of the nodule and holding many inclusions of quartz, sillimanite, and other constituents. The irregular and indented outline is quite distinct in appearance from the finely fretted or lace-like boundary presented by the muscovite of the granite, the outlines being quite sharp. It may, however, be regarded as this structure on a much larger scale. It has the eminent basal cleavage characteristic of this mineral, with the uniform extinction parallel to it.

The sillimanite occurs in long, slender, isolated needles, felted into nearly opaque masses. It occurs penetrating both the quartz and muscovite, but, as has been mentioned, is especially abundant in the feldspar, which is usually crowded with needles

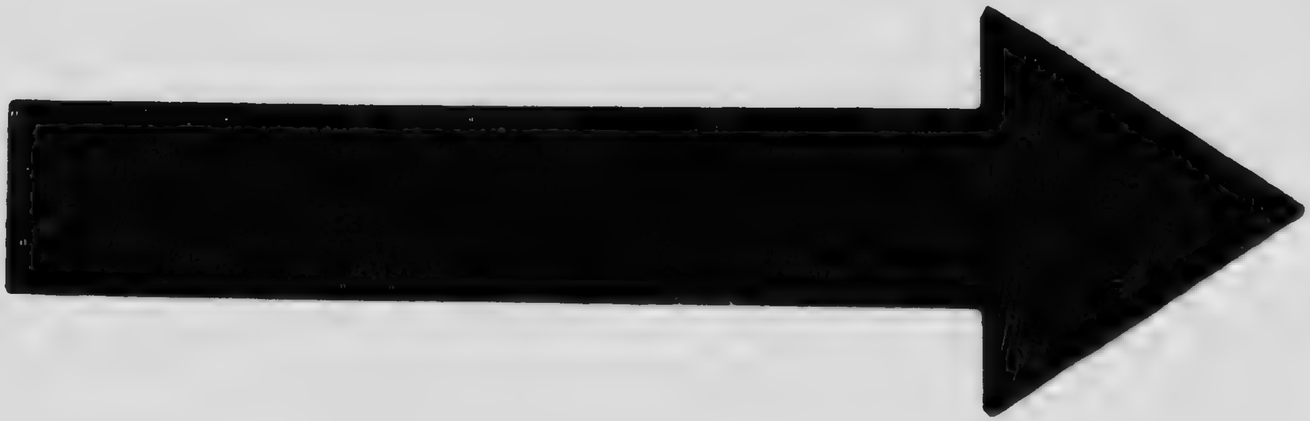
of it. The sillimanite individuals are usually very small, and are irregular in cross section. There is, however, a tendency to develop the nearly square, or the eight-sided prismatic forms usually seen in this species, and the larger grains show the usual good cleavage in the direction of one pinacoid. The mineral is uniaxial and positive.

In one or two instances, an individual of muscovite could be seen at its extremity to pass into a bundle or brush of sillimanite fibres.

The occurrence of sillimanite in granite, except along sheer zones, is, it is believed, unknown, but the mineral often abounds in the quartz which occurs in veins and irregular masses in highly altered rocks in the vicinity of granite intrusions, and elsewhere. Whether such veins have any genetic relation to such occurrences as those here described is a question for future investigation to decide.

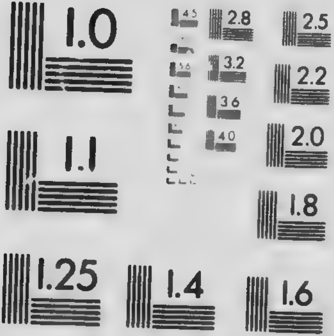
The feldspars are present in some nodules in considerable amount; in others they are practically absent. When present they consist in part of well-twinned plagioclase, and in part of an untwinned feldspar, probably orthoclase. Microcline is never found in the nodules, although it may abound in the surrounding granite. The feldspar, especially the orthoclase, occurs in irregular-shaped individuals having the feather-like forms seen in spherulites, often with an indistinct radial arrangement, and sometimes showing a granophyric intergrowth with the quartz. It is not especially abundant in any part of the nodule, and is crowded with bundles and mats of sillimanite needles. The iron ore, which is black and opaque, occurs in each nodule in the form of a few rather large grains. A grain or two of pyrite is also usually present. The tourmaline thus far found occurs as a bunch of grains, irregular in shape, dark in colour, and with strongly marked pleochroism, in pale grey and dark grey-blue tints. It is uniaxial and negative. It is associated with quartz and feldspar, and, in one or two cases, was seen to be penetrated by a few sillimanite needles.

In order to make a comparative study of the chemical composition of the granite and the nodules, a specimen was selected, consisting of the typical granite, in which there was enclosed a nodule, spherical in shape and 2 inches in diameter. The specimen was broken up, and the granite, excepting that immediately



MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No. 2



APPLIED IMAGE Inc

surrounding the nodule, was crushed, and an average sample of it drawn. The nodule, after having been very carefully freed from the adhering granite, was broken across and one half taken for analysis. The analyses (for which I am indebted to Prof. Nevil Norton Evans, of McGill University), were in each case carried out in duplicate, the figures given below representing the mean of two closely concordiant determinations:

	Granite	Nodule
SiO_2	78·83	81·43
Al_2O_3	10·88	13·70
Fe_2O_3	1·63	1·58
CaO	0·22	0·37
MgO	0·35	0·06
K_2O	5·31	1·28
Na_2O	2·13	1·02
H_2O	0·32	0·92
	99·67	100·36

Boracic acid was not looked for. The silica in a second nodule was found to amount to 79·19 per cent.

The analyses bring out the fact that the granite is a very acid one, containing much more potash as compared with soda than in the case of the granites already described, and that the chief difference between it and the nodules is, that the latter are richer in silica and alumina, and poorer in alkalis, than the granite itself. Among the minor differences is the marked preponderance of potash over soda, the smaller percentage of lime, and, owing to the presence of the biotite, the larger percentage of magnesia in the case of the granite.

A study of thin sections of this particular specimen of granite showed it to be composed chiefly of quartz and microcline, with a small amount of biotite, plagioclase, and an untwinned feldspar, probably orthoclase. Very small amounts of muscovite and iron ore were also present. As, unfortunately, in these analyses the percentage of the total iron present in a ferrous state has not been determined, it is impossible to calculate accurately the percentage of the several minerals actually present. In the case of the granite, however, there is approximately 45·5 per cent of

quartz, and 50 per cent of feldspar. The calculation of the norm of the granite, adding the ferric oxide as such, shows it to be as follows:

Quartz	45·42	per cent.
Orthoclase	31 14	"
Albite	17 82	"
Anorthite	1·11	"
Corundum	1·33	"
Hypersthene (MgO, SiO_2)	0 90	"
	97 72	
Ferric oxide and water	1 95	
	99 67	

The granite, therefore, falls into the following position in the C.I.P.W. quantitative classification:

Class I. Persalane.
Order 3. Columbare.
Rang 1. Alaskase.
Sub-rang 2.—Magdeburgose.

In the case of the nodule, the norm when calculated is found to be as follows:

Quartz	69·72	per cent.
Orthoclase	7·78	"
Albite	8·38	"
Anorthite	1 95	"
Corundum	9 89	"
Hypersthene (MgO, SiO_2)	0·10	"
	97·82	
Ferric oxide and water	2·50	
	100·32	

The peculiar magma which separates from the cooling granite mass and constitutes these nodules, and the veins or dikes into

which they pass, has, therefore, the following position in the quantitative classification:

Class I. - Persalane.
Order 2. - Belgare.
Rang 2. - (Domalkalic).
Sub-rang 3. - (Sodipotassic).

As a magma of this composition has not as yet had any name assigned to it in the classification, it is proposed to name it Cardiffose, after the township in which the rock occurs.

In these nodules corundum, of course, does not separate out, the excess of alumina being combined with silica to form sillimanite. If the excess of alumina be so calculated, and the very small amount of muscovite which is present be neglected, the nodule will be found to have the following mineralogical composition:

Quartz, 63·90 per cent; feldspar, 18·11 per cent; sillimanite, 15·71 per cent, which, together with 2·60 per cent of the ferromagnesian constituents and water, completes the sum of the analysis.

Granites, and allied rocks, containing spheroidal or concretionary lumps or nodules, are known from many parts of the world, and some of these occurrences are frequently mentioned, as, for instance, the concretionary granite from Fonni, in Sardinia, the pudding granite from Vermont, and the orbicular diorite from Corsica.

The origin of these structures is not, however, in all cases thoroughly understood; but in an elaborate memoir[1] on the subject, von Chrustschoff has presented the results of a very detailed comparative study of a large number of such occurrences, and believes them to be genetically divisible into four groups:

(1.) Concentric, spheroidal, and concretionary growths about foreign inclusions.

(2.) Nodular growths about fragments of secretions or inclusions, which latter are often partially or wholly re-dissolved.

(3.) Group of the so-called pudding granites, where the structure is due to a simple concretionary action set up in the magma during its normal crystallization.

[1] Mémoires de l'Académie Impériale des Sciences de Saint Pétersbourg, Série vii, Tome xlii, No. 3. 1894.

(4.) Primary structural forms of the magma or endomorphic contact products.

In the Pine Lake occurrence we evidently have to do with the case of primary magmatic differentiation, for although, in the case of the occasional vein-like forms, the mode of occurrence is such as to suggest a development subsequent to the crystallization of the granite, the fact that these pass into spherical nodules precisely identical with those which occur scattered as isolated individuals through the rock far and wide, and which are far more abundant than the streaked or vein-like forms, proves that they are both identical in origin, and are derived from the crystallization of a magma which was free to gather itself into rounded drop-like forms which the isolated portions of such a liquid would take, but which could not be developed in a magma when crystallization was far advanced. The constituent minerals of the nodules, furthermore, are not identical with the last formed constituents of the granite, as they should be if the nodules represented the last products of the crystallization of the granite magma. Microcline, which is abundant, and one of the last minerals to separate out of the magma in the case of the granite, is entirely absent from the nodules; while sillimanite, which is never found in the granite, is one of the most abundant constituents in the nodules, as well as one of the first of the constituents to crystallize.

The peculiarity of the present occurrence lies chiefly in the fact that the portion of the magma which thus separated out was more acid than the magma as a whole, and richer in alumina, which is very unusual. It must be remembered, however, in this connexion that the granite itself is more acid than usual.

Magmatic differentiation has been put forward by Bäckström to account for the origin of the nodular granite found at Kortfors, in Sweden,[1] in which, however, the nodules are more basic than the granite itself, as well as to explain other allied occurrences. He thinks that "it is in many cases evident that the inclusions were *soft*, and then the simplest view is that they were drops or portions of a partial magma, which, at the temperature existing immediately before crystallization, could no longer be held in solution by the principal magma, but separated out."[2]

[1] Tvenne Nyupptäckta Svenska Klotgraniter. Geol. Foren. i. Stockholm Förh. 1894. p. 128.

[2] Helge Backstrom: Causes of Magmatic Differentiation. Journal of Geology, vol. i, 1893, p. 778.

This seems to be the only satisfactory explanation of the Pine Lake occurrence, the history of whose development seems to have been as follows: In the original magma there were certain *schlieren*, richer in silica and alumina than the rest of the magma, and containing also a certain amount of boracic acid. How these came into existence, whether by segregation or separation from the immediately surrounding magma, or whether brought into their present position from another part of the mass by movements in the molten magma, is uncertain. There are, however, examples of such differentiation in granite magmas, in the case of pegmatite veins, which at their extremities frequently run out into veins of quartz, associated with a little tourmaline. These *schlieren*, being evidently immiscible with the main mass of the magma, were analogous to globules, streaks, or sheets of oil in water, except that the magma being much less mobile than these fluids, the *schlieren* could not so readily run together into globules or rounded masses. They might be compared with the globulites which separate from a solution that is about to crystallize, and which after appearing separately, aggregate themselves together into rows like strings of beads, and eventually develop into various incipient crystal forms, as shown by Vogelsang and others in their experiments on the crystallization of sulphur. Any very small isolated *schlieren* that were developed through the magma, or detached from the larger *schlieren* by movements in the semi-fluid mass, would of course, without encountering much resistance, take upon themselves a globular form, while in the case of larger streaks and sheets more resistance would be offered by the stiffness of the magma, and the tendency to assume a globular form would be less pronounced.

When the magma had cooled sufficiently, and crystallization began to set in, the solidification, in the case of the granite, followed the usual course; while the *schlieren* and globules, having a marked difference in composition, or perhaps because they contained a greater proportion of mineralizers, developed during crystallization a tendency to spherulitic arrangement. In the case of the separate nodules, the crystallization seems to have started from the centre and to have proceeded outwards, and, toward the extremity of the *schlieren*, to have commenced at a series of points along the medial line. The medial line of the schlieren thus corresponds to, and is identical in character with the central portions of the nodules.

The possibility of the nodules having been produced by the melting down of portions of some fibrolitic band in the wall-rock is eliminated by the fact that not only are such bands not found in the wall-rock, this being everywhere a basic gabbro-like amphibolite, entirely different from the nodules in composition and character, but also by the zonal arrangement often observed in the nodules, and their passage into the indistinctly banded vein-like forms which, as before mentioned, in some cases divide and fork, and are thus clearly not portions of the wall-rock.

Whether any of the quartz veins so commonly found associated with granite-gneisses of undoubted igneous origin in the Archaean, or the quartz veins and strings, often rich in sillimanite, found abundantly in the altered rocks surrounding great granite intrusions of later date, have the same primary origin as those in the Pine Lake granite, is a question worthy of investigation. The study of this occurrence shows that contemporaneous veins of an acid character may be formed, not only during the final stage of crystallization, as in the case of the hysterogenetic *schlieren* and the Kluftblätter of Reyer, but that highly siliceous portions are sometimes segregated or differentiated out of a granite magma before crystallization. Moreover, the banded structure often seen in pegmatites and other allied bodies, and sometimes cited as proof of their aqueous deposition in pre-existing fissures, is not necessarily so produced, but, as is now being generally recognized, may and usually does result from the primary crystallization of the cooling magma.

PEGMATITE DIKES.

The term pegmatite was first suggested by Haüy in 1822, to designate those regular intergrowths of quartz and feldspar which are now known as graphic granite. In 1849 Delesse extended its use so as to cover all very coarse-grained granites. Since that time the word pegmatite has been generally adopted for the entire group of coarse-grained granitic rocks, usually occurring in the form of dikes, and even for the corresponding equivalents of other plutonic masses, as, for instance, syenite-pegmatite, diorite-pegmatite, gabbro-pegmatite, etc.

In this area the true pegmatites, or what may be termed the granite pegmatites, are very abundant, but syenite pegmatites and nepheline syenite pegmatites also occur. These two latter

classes of rocks, however, will be considered in that portion of the report dealing with the nepheline syenites, while here the true granite pegmatites alone will be described.

As has already been mentioned, the granites and granite-gneisses, in all parts of the area, very commonly contain ill defined and irregular-shaped bodies of pegmatite. This is sometimes in the shape of large splashes, which Lehmann has so fittingly termed "flammen[1]", from the flame-shaped forms which they commonly assume. At other times it occurs distributed throughout the whole body of the rock in smaller masses of less grotesque shape, which, when there has been a distinct movement of the rock in one direction, are elongated into coarse-grained streaks. These consist of quartz and feldspar, but are usually poorer in iron-magnesia constituents than the rest of the granite.

These coarse-grained portions seem to be the last portion of the granite magma to solidify, and where the granite batholiths shatter the strata through which they are rising, it is this coarse pegmatitic facies of the granite which oozes into the final cracks and fissures, filling them up and forming what are commonly known as pegmatite dikes. These dikes are thus found traversing every other rock type in the area, and are especially abundant in certain places where the overlying crust is thin, or where on the margin of the intrusion the invaded rock is fraying away into the uprising granite. Thu in the great body of limestone and rusty sedimentary gneiss which is squeezed in between the batholiths of Burleigh and Anstruther in the west and south, the Methuen batholith on the east, and the mass of granite occurring in southern Chandos on the north, these pegmatite dikes abound. They are also common everywhere in the limestone bands which lie between the batholiths in the western half of the Haliburton sheet; while in the southeastern corner of the Haliburton and Bancroft sheets, the overlying sedimentary cover being thicker, and the granite much less abundant, pegmatite dikes are comparatively rare. Furthermore, in the batholiths and areas of granite-gneiss themselves, where the rock, in the movements to which it has been subjected while still in a more or less pasty condition, shows by the abrupt interruption of the foliation that it has been faulted — the slow and gradual movements by which the foliation originates

[1] Untersuchungen über die Entstehung der altkrystallinischeen Schiefergesetine. Bonn, 1884. Page 24 et seq.

PLATE XXI.

Pegmatite dike (containing tourmaline) cutting granite gneiss and amphibolite. Little Madawaska river, north of Barrys Bay, Ont.

being interrupted locally by a more sudden movement along the line of rupture it is found that a mass of pegmatite always fills the resulting space. (See Plate XXI.) The pegmatite in this case is usually not very sharply defined against the rest of the granite, but to a certain extent fades away into it. An admirable example of such an occurrence, on a large scale, is seen in the fault along the east side of the Burleigh batholith referred to on page 20. Again, when in the development of a batholith the granite-gneiss at any point is very sharply curved, pegmatite is apt to appear, as if to fill ruptures which had been developed. This is well seen in the Burleigh batholith, on the sharp bend between Long lake and Trout lake, on lots 14, 15, and 16, of concessions V and VI of Burleigh, where a great body of pegmatite, varying much in size of grain, appears. Evidently in these cases portions of the still fluid magma from below, or occurring through the body of the still but partially solidified rock, have passed into the spaces as they were opening, or after they had opened, and have filled them.

Pegmatite in fact is the universal healer of all wounds and dislocations in the various rocks of the area.

The pegmatite dikes vary greatly in width, from mere strings an inch or even less in width, up to great dikes many feet, or even yards across. (See Plate XXII.) In the northwestern part of the Haliburton sheet they seldom exceed 6 feet in width, the largest dikes in the area being those occurring in Methuen and Burleigh. One of these, on lot 2, concession XII of the latter township, is 250 feet wide, while others in the same district are even larger. With a greater width than this the pegmatites lose their dike-like form, and are apt to take the shape of more or less lenticular masses, like that running off to the southwest from the southwestern bay of Jack lake, on the east side of Burleigh. These very large dikes and masses, however, seldom preserve throughout their extent the very coarse grain of the true pegmatites, but tend to approach the normal granite type. One of the largest pegmatite masses in the area, which does preserve its true pegmatitic facies, is that which occurs on concessions XI, XII, and XIII, of Monmouth, stretching from lots 6 to 17, and having an area of nearly three and a half square miles. The longest dike seen anywhere in the area is that which runs with a curving course across Jack lake in the township of Methuen, from lot 5 of concession VII to lot 15 of concession IX, a distance of four miles.

The pegmatites consist almost exclusively of quartz and feldspar. Iron-magnesia constituents are present only in very small amount, being represented either by a black mica, or by occasional small segregations of magnetite. Two feldspars, orthoclase or microcline, and a lime-soda feldspar can frequently be recognized even on the weathered surface, the former assuming a pale pink and the latter a grey colour. Under the microscope the feldspars often present beautiful microperthitic intergrowths, as for instance, in the pegmatite of lot 15, concession XII of Monmouth, where the potash feldspar is intergrown with an oligoclase, the large microperthite individuals having a specific gravity of 2·629. Other minerals are not common, although probably, if the dikes come to be extensively worked for feldspar at any time, the rarer minerals which occur elsewhere in these rocks would from time to time be found. Masses of a black isotropic mineral, apparently a garnet, the largest of them about 6 inches square, were obtained from a body of pegmatite which underlies the greater part of the front of lot 12, concession I of the township of Minden. Black tourmaline occurs, although in small quantity, in the pegmatites in many places. As an instance, those occurring about Clear lake, on lots 24, 25, and 26, concession III of Methuen, may be cited. This mineral is most likely to be found when the pegmatite becomes very rich in quartz, and proportionately poor in feldspar.

In a single instance graphite was found in a pegmatite dike. This remarkable occurrence is on lot 38, concession I of the township of Anstruther. A description of this occurrence is given on page 370, in the section dealing with the economic resources of the area. The interest which attaches to this occurrence is that the graphite here occurs in an igneous rock, and might thus, like the other constituents, be naturally considered as derived from the cooling of the original magma. The igneous origin of graphite in this case, however, is not indisputable, seeing that the dike cuts highly altered limestones, and the carbonaceous material may have been introduced from them.[1]

[1] See Kemp, J. F. Pre-Cambrian Sediments in the Adirondacks. *Science*, July 20, 1900, where, in discussing the origin of the graphite in the limestone, the author writes: "Despite of the occurrence of very small amounts (of graphite) in the igneous rocks, my own opinion from the preponderating evidence is that it has been derived from the limestones, quartzites, and gneisses, and has only been worked over, caused to migrate, and recrystallized by the metamorphosing agents."

PLATE XXII.

Pegmatite dikes intersecting amphibolite. A small dike (younger) is seen cutting across a larger dike. Near Killaloe, Ont.

In the great majority of cases the mineralogical composition of the pegmatite does not seem to be influenced in the least by the character of the wall-rock. Thus, the great swarm of pegmatites cutting the crystalline limestone in the township of Burleigh have the same composition and character as those which occur cutting the granite-gneiss. In the southwestern part of the area covered by the map sheets, however, the pegmatites which cut the great intrusions of amphibolites and other basic rocks occurring in the gneiss, very frequently hold a considerably larger proportion of biotite than the pegmatites normally contain. In these cases it would seem that some material had been supplied by the wall-rock, but, as above stated, speaking generally, no influence on the part of the wall-rock can be observed.

The structure of the pegmatite dikes may be described as coarse-grained, and more or less irregular. A rapid variation from place to place—in some cases even within a few feet—from coarse to rather fine, is characteristic. The extreme coarseness of grain seen in some other regions, where feldspar individuals several feet in length are found, is not observed in the dikes of this area. In the pegmatites of New Hampshire, feldspars are frequently found as much as 10 feet in length, and one crystal in the American mine, in Groton, measured fully 20 feet, while Brogger mentions feldspar crystals in the Norwegian pegmatites, 10 metres (nearly 33 feet) in length.[1]

The feldspar individuals in this area are seldom over 6 or 7 inches in diameter. Few of the dikes show in any very striking manner the graphic granite intergrowth of the quartz and feldspar often so perfectly developed in pegmatites, but there is generally a tendency to this intergrowth, which influences the structure of the rock.

In a few cases, however, a very coarsely miarolitic structure is observed, and the large drusy cavities, or vugs, are occupied by large crystals of orthoclase and quartz, together with biotite. A good example of such an occurrence was observed at a mica mine situated on lot 18, west of the old Hastings road, in the township of Herschel, a short distance north of Bird Creek post-office. Some of the crystals of orthoclase at this locality, with sharp and well defined crystallographic outline, measure nearly 2 feet

[1] Canadian Record of Science, vol. 6, No. 67.

in diameter, while the hexagonal crystals of quartz, with pyramidal termination, are often from 1 to 2 feet in length, and from 2 to 5 inches in diameter. The quartz crystals illustrate in a very perfect and clear manner the successive stages in their development, many of the larger individuals being formed by the coalescence, or growing together of several neighbouring crystals, the interspaces being occupied by silica in perfect optical continuity.

To the south of the road between Maynooth and Combermere, about nine miles east of Maynooth, a similar occurrence was noted, but here the constituents of the dike were orthoclase, albite, and calcite. The orthoclase crystals were often over a foot in diameter, with sharp crystal planes, while the albite, though not so large, was even more perfectly developed. The centre of the dike was largely occupied by irregular masses of coarsely crystalline calcite, and occasional perfectly developed crystals of albite were completely enclosed in the calcite. The calcite was evidently due to the same action as that to which the feldspars owe their origin. (See Plates XXIII and XXIV.)

A distinct arrangement of the minerals parallel to the sides of the dike is not common, although in many dikes a certain general tendency to parallelism, banding, or crustification can be seen. Such a structure is manifestly primary. Frequently, however, especially in the dikes of the western side of the area, a distinct parallelism of a different character can be observed in the pegmatites. This consists in a more or less well pronounced foliation of the pegmatites. This structure, as has been shown in treating of the granite-gneiss, is one which, in the case of the great batholiths of this rock, results from movements in the solidifying mass, which cause the rock first to pass through the stage of an augen gneiss, and finally, when the augen have been destroyed, into a fine-grained laminated gneiss.

A similar foliation in all its stages can be excellently seen in the pegmatites from many parts of the area; in fact it is, in a more or less pronounced form, very common almost everywhere. Magnificent developments of pegmatite in the augen gneiss stage are to be seen in the hills east of the village of Minden, and it is well shown in the great area of pegmatites on concessions XI, XII, and XIII of Monmouth, referred to on page 141. In the latter case the foliation, or streaked structure of the pegmatite,

PLATE XXIII

Miarolitic cavity in pegmatite dike, showing large crystals of orthoclase, lot 2, concession III, Bangor township, Ont.

Miarolitic cavity in pegmatite dike, with large crystals of orthoclase and albite. The calcite originally occupying the interstices between the crystals has been removed by weathering.
Lot 2, concession III, Bangor township.

follows the outlines of the mass. The movements in the pegmatite during cooling, and before solidification, produced in it, in fact, the same effects as in the case of the granite-gneiss itself.

There are certain cases, however, when the foliation of the pegmatites can be seen to have been produced by movements not connected with the upward flow of the magma in the fissure, but with region pressure after the magma had filled the pressure and was solidifying, or possibly was already solid. Thus there are, on lots 8, 9, and 10 of Minden, along the boundary with Snowdon, a number of small pegmatite dikes, cutting a mass of foliated, dark coloured, basic rock. In these dikes, which cut diagonally across the direction of the foliation of the enclosing rock, a foliation has been induced, which, instead of being parallel to the course of the dike itself, runs across the dike and is parallel to the foliation of the basic rock which the dike penetrates. In this case it is clear that the foliation of the pegmatite is due to the same cause which gave rise to the foliation of the basic rock itself. It is probable that in this case the foliation was induced at a time when both rocks were very highly heated, and quite possibly before the injected pegmatite had completely solidified.

The pegmatites are prevailingly rich in feldspar, this constituent largely predominating over the quartz. In places, however, this latter constituent becomes more abundant, especially at the extremity of the dike when it becomes narrow. In fact, cases can be observed where the feldspar is represented only by a few individuals here and there, and the dike develops into a mass of quartz. Such an occurrence, if seen alone, would undoubtedly be considered as a quartz vein, but in this area no genetic distinction can be drawn between the two occurrences. The quartz veins, in these cases at least are merely a form or phase of the pegmatite dikes. This relation is well seen in the township of Methuen, about the shores of Kasshabog lake (see page 81), and it is important in connexion with the consideration of the question of the origin of mineral veins as a class.

There is hardly any group of rocks which enters largely into the composition of the earth's crust whose origin has been the subject of so much study and discussion as the pegmatites.[1]

[1] See Williams, Geo. H.—Origin of the Maryland Pegmatites. 15th Ann Rep. U.S.G.S., pp. 675 to 686.

Charpentier, who was one of the first to study these rocks, regarded them merely as contemporaneous injections of the residual granite magma, and hence, as the final step in the process of granitic consolidation.[1] He was followed in this idea by De la Beche, by Bronn, Fournet, Durocher, and Angelot. Naumann is also inclined to think this the most probable theory, and calls them afterbirths of the granite.[2]

Elie de Beaumont, in his famous essay, "Sur les Emanations volcaniques et métallifères,"[3] while accepting in the main the igneous and intrusive origin of pegmatites, introduced an important addition, in assuming water and other mineralizing agents as necessary factors in their formation. He correlated the pegmatites with the other phenomena so common in the peripheral regions of granitic districts, or, as he called it, granite aura (the penumbra of Von Humboldt). De Beaumont, while assuming granitic emanations as necessary for the crystallization of the coarse-grained granites, is careful to distinguish between them and the banded concretionary veins formed by substances dissolved in circulating heated waters.

Scheerer, in a paper published about the same time as that of De Beaumont, attributed a still more important role to water in the formation of pegmatites, holding what Hunt has designated as the theory of granitic juice, a highly heated aqueous solution of mineral substances impregnating the congealing mass, and oozing out under pressure into the surrounding rocks.[4]

The intrusive theory of the origin of pegmatite, with the aid of water and other mineralizers as important factors, has more recently been advocated by J. Lehmann[5] and by Brögger,[6] and may be regarded as the most acceptable for all those masses which are in intimate association with larger plutonic intrusions. These two authors differ, in that the former assumes a viscous or colloid state of the material at the time of its injection into the fissures surrounding the granite mass, and thinks that no high

[1] Essai sur le Const, geogn. des Pyr., p. 158, 1823.

[2] Lehrbuch der Geognosie, 2d ed., vol. 2, p. 232, 1858.

[3] Bull. Soc. Geol. Fr., (2) iv., p. 12.

[4] Bull. Soc. Geol. Fr., (2) iv. p. 468, 1847. T. Sterry Hunt; Chem. and Geol. Essays, p. 189, 1875

[5] Ueber die Entstehung der altkrystallinischen Schiefergesteine, p. 24 et seq., 1884.

[6] Die Syenitpegmatitgange der südnorwegischen Augit und Nephelinsyenit, I. Theil., pp. 215-225. Zeitschr. für Kryst., vol. 16, 1890. Translated by N. N. Evans, Can. Rec. Sc., vol. VI, Nos. 2 and 3, pp. 33-46 and 61-71.

temperature is necessary; while the latter regards the pegmatite dikes as formed under more normal igneous conditions, although allowing the importance of mineralizing action. A similar aqueo-igneous theory for the origin of pegmatite has been advanced by W. O. Crosby.[1]

To quote the words of Williams: "the writer's conception of the relation between these intrusive pegmatites, and the granite with which they are associated, does not materially differ from the conceptions of De Beaumont, Lehmann, and Brögger. We are accustomed to connect coarseness of crystallization in igneous rocks with slowness of solidification, and while this is doubtless a correct conception, it does not necessarily follow that very coarse-grained rocks are always produced in this way. If the facility of molecular motion be sufficiently increased, and the conditions of crystal growth are thereby rendered more favourable through the presence of volatile substances, we may get coarse-grained mineral aggregates in a comparatively short period of time. The writer interprets those pegmatites as the products of the residual, and, therefore, most acid portion of a granite magma highly charged with water and other mineralizing agents. Such a siliceous material, in a state intermediate between fusion and solution, has been injected into fissures, and there crystallized into very coarse-grained aggregates, not necessarily through any great slowness of this process, but rather in virtue of the aid to crystallization afforded by the abundance of mineralizers present."

[1] American Geologist, vol. 13, p. 215, March, 1894. Also Technology Quarterly, vol. IX, Nov., Dec., 1896, pp. 326-356.

GABBROS AND DIORITES.

It is a matter of difficulty in this area to draw a satisfactory line between these rocks which should be coloured gabbro and diorite and those which should be represented as amphibolite. These masses, however, which have been designated as gabbro and diorite, whatever be their precise petrographical nature at present, have all the characters of great basic intrusions, and are either perfectly massive or show only that variation in size of grain from place to place with the irregular streaked structure due to movements in such a mass, which are often displayed in occurrences of typical gabbro. They differ from the amphibolites, therefore, in the absence of a prevailing foliated structure, and, as a general rule, in their mode of occurrence also.

In the limestone series in the vicinity of these intrusions there are often found dike-like masses, which, while sometimes practically massive, at other times show a more or less distinct foliation, which causes them to be classed as amphibolites. They are, nevertheless, evidently dikes sent off from those great intrusions, but whose original character has been obscured by subsequent dynamic action.

It will be sufficient to describe some six occurrences of the gabbro and diorite, which may be taken as representative of the intrusions of these classes of rocks occurring in the area. These are: first, the three great masses which are crossed by the Hastings road, the most northerly at the meeting point of the four townships of Faraday, Dungannon, Limerick, and Wollaston; the second in the townships of Wollaston and Limerick; and the most southerly in the townships of Lake and Tudor. These will be referred to as the Umfraville, Thanet, and Tudor masses respectively. The other three occurrences of gabbro and diorite which will be considered, are a group of intrusions in the northern part of Chandos, an area about the centre of Wollaston, and the great mass stretching across the south of the township of Glamorgan.

Rough and rocky country underlaid by Umfraville gabbro, road between Faraday P. O. and Hastings road lot 2, concession I, Faraday township.

Microphotograph of hypersthene gabbro, showing hypersthene, augite, and plagioclase, lot 2, concession I, Faraday township. Ordinary light. Magnified 22 diameters.

UMFRAVILLE GABBRO.

This rudely triangular occurrence, as has been mentioned, occupies the area where the four townships of Faraday, Dungannon, Limerick, and Wollaston meet. As in the case of the other occurrences of the rock, it gives rise to a very rough and broken country of comparatively little value for purposes of agriculture. (See Plate XXV.) The mass is well exposed along the road following the rear line of Wollaston, where it is seen to be massive in character, but frequently to present an irregularity in grain—coarser and finer being usually very basic and often having a streaked structure. It is in many places cut by pegmatite dikes.

A specimen collected on lot 2, concession I of Faraday, which is about the centre of the mass, when examined under the microscope was seen to be a typical hypersthene gabbro. It is composed of hypersthene, augite, hornblende, and plagioclase, with accessory biotite, iron ore, pyrrhotite, apatite, and calcite. The hypersthene shows the usual character of a rhombic pyroxene, with faint trichroism in reddish, greenish and yellowish tints, and also low double refraction. It has a better crystallographic form than the augite and in places shows an incipient alteration to a serpentine-like product. The augite is pale in colour, shows a high extinction angle, and often contains the little brown plate-like inclusions frequently seen in diallage. The hornblende is apparently not an original mineral but is derived from the alteration of the augite, being often seen in little spots occurring through an augite individual and all similarly orientated. The plagioclase individuals are sometimes seen to be bent or even partially broken. The biotite occurs in considerable quantity, is brown in colour, strongly pleochroic and occurs associated with the other bisilicates. The calcite occurs in small amount but in rather large individuals, filling the interspaces between the other constituents, or in inclusions in the feldspar or other minerals, often near the hornblende, which is suggestive of a secondary origin. (See microphotograph, Plate XXVI.)

Specimens from the southern portion of the mass were collected near the shore of Bald lake, in lot 7 of concession XIV of Wollaston. Here the rock is fairly uniform in character and in a hand specimen has the appearance of a typical gabbro, but

under the microscope pyroxene is found to be absent, its place being taken by hornblende. The hornblende, however, almost everywhere possesses a fibrous character, the masses being pale green in the centre and deeper green around the border. They hold, moreover, minute, irregular-shaped, colourless inclusions, the whole suggesting that the hornblende is secondary and derived from the alteration of pyroxene. Other specimens taken from near the southwest border of the mass show this change (or as-ociation) in all stages.

THE THANET GABBRO.

This mass is also crossed by the Hastings road and occurs in the southern portions of the townships of Wollaston and Limerick. It is oval in shape and stretches a little over four miles in the direction of the longer axis.

It breaks through the limestone-amphibolite series of the surrounding district, sending out dikes into it and holding great inclusions of it. The rock is practically massive, although it often has a very indistinct tendency to foliation parallel to the strike of the rocks through which it is intruded. It varies from rather coarse to rather fine in grain. Specimens from the Hastings road on lot 23 of concession A of Wollaston, which is about the centre of the mass, and others from Lighthouse lake, lot 3 to 6 of concession IV of the same township, near the southeast margin of the intrusion, were examined. The rocks from these two localities resemble each other very closely. They are both composed of plagioclase and hornblende as essential constituents, but in both cases the hornblende presents the character of a secondary mineral after augite, and there is reason, therefore, to regard the rock as an altered gabbro. In the rock from Hastings road, on lot 23, the hornblende is rather pale green in colour and pleochroic in yellowish and pale bluish tints. It occurs in rather large but ragged individuals, often having a more or less fibrous character, and holding the mi ute colourless, pear-shaped inclusions so frequently seen in the hornblende of the amphibolite.

The plagioclase occurs in large amount, as well-twinned individuals, which, however, are in the act of breaking down into an aggregate of small allotriomorphic grains in which quartz, as well as feldspar, is present. A small quantity of biotite, apatite,

and iron ore are present, the latter mineral occurring, however, in surprisingly small amount considering the very basic character of the rock.

The rock from Lighthouse lake has a faintly foliated structure, with a more lath-shaped development of the plagioclase than is usual in gabbros.

The feldspar is filled with dust inclusions and encloses ramifying masses of secondary calcite, and scapolite. There is also a considerable amount of quartz present, probably, in large part at least, of secondary origin. The biotite nearly equals the hornblende in amount. Apatite and iron ore are present as accessory constituents.

THE TUDOR INTRUSION.

The Tudor mass forms a large intrusion of oblong outline, nine and a half miles long and two miles wide, the longer axis of which runs in a northeast and southwest direction and crosses from Lake into Tudor on lots 41 to 56 of the Hastings road. It cuts through the limestones and amphibolites of this portion of the area in a direction nearly parallel to their strike, sending dike-like apophyses into them and holding inclusions of them. Like the other gabbros under consideration, it forms a very rough and broken tract of country. It is well seen on the Hastings road, and rises into high, bare, rugged hills about Beaver and Otter creeks, on concessions VIII and IX of the township of Lake. In this locality the rock is quite massive, but possesses a species of eutaxitic structure, finer and coarser grained varieties occurring associated with one another, the relative proportion of the constituent minerals also varying somewhat from place to place. A specimen of the coarser variety from lot 8, on the line between concessions VII and VIII of Lake, was examined microscopically.

The rock is composed essentially of hornblende and plagioclase, with accessory quartz and biotite. The hornblende is pale green in colour, often somewhat fibrous in character, and frequently holds minute, pear-shaped inclusions of quartz and calcite, especially the former. The intensity of the colour also is frequently seen to vary from place to place. The character of the mineral suggests that it has been derived from pyroxene, but there is no proof that such is the case. No pyroxene is present in the sections. The plagioclase occurs in well defined individuals showing polysynthetic

twinning, but is filled with minute grains of zoisite. The quartz is present in small amount and is probably primary, occurring in the corners between the plagioclase individuals.

In absence of proof of the secondary origin of the hornblende, the rock must be classed as a diorite.

OTHER GABBROS.

There are also several small intrusions of gabbro-diorite in the northern portion of the township of Chandos, two of the largest being situated on lots 18 to 26 of concessions XVII and XVIII of this township. The rocks composing these intrusions are coarse in grain, and either quite massive in character or showing in places a very indistinct foliation.

A specimen of this rock taken from lot 23 of concession XVII, near MacDonald rapids where the rock is uniform in character and possesses a very faint foliation, when examined under the microscope was seen to be composed of hornblende and plagioclase, with accessory iron ore, apatite, and sphene.

The hornblende occurs in fairly compact individuals, but holds many little irregular-shaped grains of colourless quartz, and has a serrated border, penetrating the plagioclase individuals, with little crystal terminations.

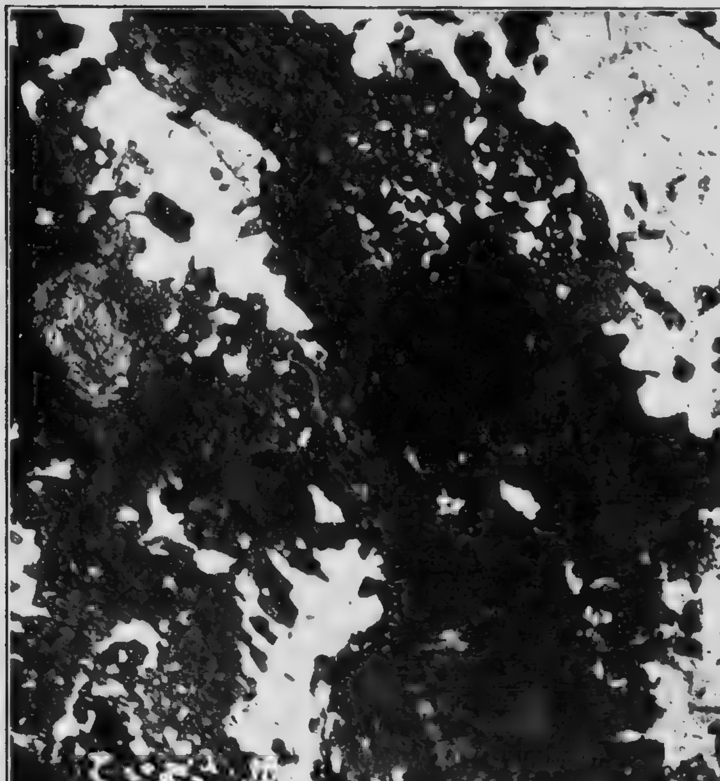
The plagioclase occurs in large individua and is usually well-twinned. Some untwinned feldspar, which is probably plagioclase, is also present.

The iron ore occurs in large individuals, each surrounded by a border composed of smaller grains of sphene. The apatite occurs as occasional crystals or irregular-shaped grains. No quartz or biotite is present. (See microphotograph, Plate XXVII).

Specimens from the adjacent intrusion on concession XVIII of Chandos, and passing into the adjacent township of Cardiff, when examined under the microscope show that this rock has essentially the same character, although containing relatively more hornblende. The plagioclase, furthermore, in some cases can be seen to have been granulated, while the hornblende frequently occurs in aggregates of little allotriomorphic grains.

These rocks are also diorites, although the character of the hornblende strongly suggests that it is derived from the alteration of pyroxene, and that the rocks may really be altered gabbros.

PLATE XXVII



Microphotograph of gabbro-diorite, showing hornblende (with inclusions plagioclase, and iron ore (with rim or border of sphene), lot 2, concession XVII, Chandos township. Ordinary light. Magnified 44 diameters.

Another occurrence of the same general character is represented by a lenticular-shaped mass which cuts across the strike of the limestone series on lots 19, 20, and 21 of concession IX of Wollaston. The rock shows a considerable difference in colour in various parts of the mass, ranging from grey to black, and also changes considerably in texture, being in some places fine in grain and elsewhere coarsely crystalline, showing in places a species of eutaxitic structure. It is composed essentially of plagioclase, pyroxene, hornblende, and biotite, but very frequently holds in addition considerable amounts of scapolite, epidote, and calcite, and in some specimens microcline and quartz. Iron ore, pyrite, apatite, and sphene are also present as accessory constituents.

There is a very considerable amount of pyroxene in the rock. It is a pale green augite and is almost invariably associated with the hornblende in a most intimate manner, the hornblende occurring as flecks scattered through the pyroxene individuals, or in other cases as an almost continuous network, increasing in amount until it largely preponderates in the composite grain. The hornblende possesses a much deeper green colour than the augite, the intensity of the colour varying considerably in different parts of the rock. The mineral is compact and not fibrous in character. While it is probable that the relation may represent a primary intergrowth of the two minerals, it is more probable that the hornblende is a product of secondary alteration.

The microcline and quartz are primary constituents, appearing, however, only in certain portions of the rock, while the scapolite, epidote, and calcite occur as large individuals penetrating or lying between the other constituents. Whether they should be regarded as primary or secondary is uncertain. The structure of the rock is peculiar. In many places it is poikilitic, the plagioclase (which is a labradorite) and the biotite holding numerous inclusions of augite, often with good crystalline form. The rock, however, is best referred to the class of the gabbro-diorites.

GLAMORGAN GABBRO.

While the intrusions already described are pretty uniform in general character, the great gabbro mass in the township of Glamorgan is characterized by a very marked differentiation of the magma, giving rise to a great variation in the composition of the rock in different parts of the occurrence.

Greens mountain, which is one of the highest points in the district, on lot 15 of concession I, forms the most westerly part of the intrusion. From this place the gabbro mass stretches eastward to the side line of the township of Glamorgan, and over into the adjacent township of Monmouth, as far as lot 11 of concession IV. It thus has a length of eight miles and a maximum width of two and a half miles.

Within this area the rock varies from a variety in which the plagioclase preponderates largely (as on lot 30 of concession II of Glamorgan), through increasingly basic varieties to a pyroxenite, as on lot 26 of concession III, or an iron ore, as on lot 35 of concession IV of the same township. No regular order could be observed in the arrangement of these different types. The rock is on the average rich in iron-magnesia constituents.

The rock also shows a considerable variation in structure. Most of it is massive, but distinctly foliated varieties also occur, as, for example, in the vicinity of Trooper lake.

The following minerals have been found in the thin sections of the rock, of which all the chief varieties were examined microscopically:—plagioclase, microcline, scapolite, pyroxene, hornblende, olivine, biotite, ilmenite, sphene, epidote, calcite, apatite, and spinel.

The plagioclase is either labradorite or bytownite, as shown by the specific gravity, determined by a number of separations conducted on specimens from different localities, made by means of Thoulet's solution. Microcline, in addition to the plagioclase, is present in the variety occurring on lot 31 of concessions II and III of Glamorgan.

Scapolite is quite abundant in many places, but is in some cases at least, and probably in all cases, a secondary constituent. It is uniaxial and possesses a high double refraction, showing the characteristic cleavage of the species with parallel extinction. It occurs either in the form of grains with well defined polygonal outlines, associated with the feldspars, or in individuals of extremely irregular shape growing through the feldspar, and associated in some cases with calcite or epidote. It is well seen, having the latter form, in the specimens from lot 23 of concession I of Glamorgan.

The pyroxene, which is a very pale green, monoclinic variety, is very abundant in many parts of the mass, but does not occur

alone in any of the specimens which have been examined. It is always intimately associated with the deep green hornblende, which occurs in little flecks and patches scattered through the pyroxene, and all usually having the same orientation, or in separate grains associated with the pyroxene. It frequently occurs in both ways in the same rock. As in the intrusions on the Hastings road, the hornblende is massive in structure, and it is uncertain whether it should be regarded as an alteration product of the pyroxene or as an original mineral. In many places the rock becomes a hornblendite, the hornblende being the only iron-magnesia constituent. Excellent examples of both varieties occur on lot 26 of concession III of Glamorgan.

Biotite is not commonly present, but is found in the foliated variety which occurs on lot 23 of concession I, and on lot 31 of concessions II and III.

A massive and very basic development of the gabbro is seen on the northwest side of Pine lake, at the eastern extremity of the intrusion. Here it is coarse in grain, and shows a beautiful development of the corona or rim structure found in many gabbros elsewhere, and which on the weathered surface of this rock is marked by the presence of orange-coloured spots (olivine and pyroxene), each surrounded by a deep green border (hornblende). A specimen of this from lot 9 of concession IV of Monmouth, when examined under the microscope, is seen to contain irregular-shaped grains of olivine, about which the corona is developed in the form of a double zone, the inner consisting of a colourless rhombic pyroxene, the elongated crystals of which stand out at right angles to the surface of the olivine, and the outer border being composed of a green fibrous hornblende similarly arranged, the individuals of which project into the surrounding plagioclase. Associated with the hornblende there are numerous minute, irregular-shaped grains of a deep green spinel.

The structure is very similar to that seen in the anorthosite of the Grand Discharge of the Saguenay river, near Lake St. John. It is well seen also in specimens from lot 11 of concession III of Monmouth, but in the sections examined the olivine is wanting, and the phenomenon is somewhat complicated by the appearance of other minerals in addition to those mentioned.

Finally, one of the most interesting differentiation phases of this gabbro mass is what is known as the Pusey iron ore body,

which is situated on lot 35 of concession IV of Glamorgan. This is a massive, heavy black rock, which when examined under the microscope is seen to consist essentially of pyroxene and iron ore. The pyroxene is of a purplish colour, having a faint pleochroism in purplish and greenish yellow tints, and toward the centre of the individuals holds bunches of minute black spicules. The pyroxene individuals are enclosed by the iron ore, but about each individual of pyroxene there is a narrow border of brown and usually highly pleochroic hornblende. The structure is well shown in the accompanying microphotograph (Plate XXVIII).

In the specimens collected, and which were supposed to represent the average character of the mass, the iron ore constituted only about one-fourth of the whole, although in the microphotograph the iron ore is relatively more abundant. From the analyses of specimens from the locality, however, by Chapman and Pope (see pp. 353 and 354 in the section dealing with the Economic Resources of the area), from two-thirds to over three-fourths of the rock must, in places, consist of ore. These analyses show the presence of about 13½ per cent of titanic acid in the rock, which undoubtedly lies almost entirely in the iron ore, which, while rather feebly magnetic, thus has a high content of titanium. It is interesting to note that Pope found the ore to contain 0·52 per cent of vanadic acid, but no chromium.

PLATE XXVIII.

Microphotograph of Pusey iron ore, showing pyroxene individuals enclosed in iron ore, with corona of hornblende surrounding the pyroxene, lot 35, concession IV, Glamorgan township. Ordinary light. Magnified 22 diameters.

THE AMPHIBOLITES.

Under the name amphibolite, as here employed, are included the dark coloured basic rocks which are so widely distributed in the area under consideration. From these are separated, of course, the great gabbro and gabbro-diorite intrusions which are mapped separately.

These amphibolites, while themselves often underlying large areas, are also found in intimate association with the granitic gneisses, the gabbros, the limestones and the sedimentary gneisses of the region. In fact, with the latter class of rocks the association is so intimate that it is often impossible in mapping to sharply separate the two, as they appear to pass into one another. Almost everywhere in the limestones, bands or masses of amphibolite are found. The gabbro areas usually are partially or completely surrounded by amphibolite. The cause of this persistent occurrence of the amphibolites is to be found in the fact that they include rocks of very diverse origin, but which, under the intense action of the metamorphic processes to which they have been subjected, have acquired a certain and often striking community of character and composition.

The amphibolites then may be defined as dark coloured basic metamorphic rocks, which have as their chief constituents hornblende and plagioclase feldspar. The hornblende is often replaced in part by pyroxene or biotite; while quartz, calcite, iron ore, and sphene are frequently present as accessory constituents.

The chief variations in the case of the amphibolites are to be found in their structure rather than in their composition. Thus, some amphibolites are very fine and uniform in grain, and with a foliation which is scarcely perceptible to the unaided eye but clearly seen under the microscope; while others, which are equally fine in grain and uniform in character, show, when a transverse surface of fracture is examined, a distinct foliation, owing to the constituent minerals having a more or less perfect parallel alignment.

Other amphibolites are rather coarse in grain and nearly massive. These bear a certain resemblance to diorites, but differ

fro[illegible] angement of the component minerals. Certain of the [illegible] types show a marked parallelism in the arrangement of the hornblende and plagioclase, the weather emphasizing this structural feature by its different action on the mineral constituents.

Another variety, which is especially prevalent on the eastern side of the Bancroft area, presents a very distinct banded structure, often without any well marked foliation. In this variety the several bands are sharp and well defined, but differ in colour, owing to the darker constituents being relatively more abundant in certain of them. In certain cases there is also a difference in the size of grain of the several bands. This parallelism gives to the minerals in the rock the appearance of a bedded deposit, which it probably is in many cases, especially when it is interbanded with thin layers of limestone, as in the case of much of the rock formation designated as limestone and granular amphibolite on the Bancroft sheet accompanying this report.

Still another widespread variety, and one of the most interesting which occurs in the area, is that which, during the course of the field work in the area, on account of the peculiar appearance which it presents on a surface of fracture parallel to the foliation, was designated as feather amphibolite. It is confined to the eastern half of the area, and almost invariably occurs in connexion with crystalline limestone, usually interstratified with it in thin bands varying from half an inch to 3 or 4 inches in thickness. So intimate is the association of these several kinds of amphibolite with one another, and so frequently do they pass into one another, that it was found impossible to separate them on the accompanying maps. An exception, however, is made in the case of the feather amphibolite, which is more distinctly marked off than the other varieties. This, as has been mentioned, occurs interbanded with crystalline limestone, and a special designation has been reserved on the Bancroft sheet for this association of crystalline limestone and feather amphibolite. The areas where the finely granular amphibolite occurs interbanded with limestone have also been separated in mapping.

The origin of the amphibolites is a question of the highest importance in the elucidation of the geology of the area, as well as one of great interest from a petrographical standpoint. A diligent search was made for occurrences of amphibolite con-

cerning whose origin there could be no doubt. In this way it was expected to prove the origin of other similar occurrences concerning which conclusive evidence of an independent nature could not be obtained. Several such occurrences were fortunately found. These have shown, beyond a doubt, that amphibolites, which in many cases cannot be distinguished apart, have been produced on one hand by the alteration of basic igneous intrusions, and on the other hand by the action of granitic intrusions on limestones. There is also reason to believe that other amphibolites have been produced in still other ways. It will be well, therefore, in the consideration of the amphibolites of the area to keep these genetic relations in view, and to consider first one of the occurrences above mentioned in which the amphibolite is of undoubtedly igneous origin.

Around the shores of Jack lake, in the township of Methuen, may be noticed one of the most extensive and typical developments of crystalline limestone in the whole area. The limestone, although coarsely crystalline is well-bedded, possessing a definite strike as indicated on the map. This limestone often contains large angular or semi-angular blocks of a very fine-grained, nearly massive black amphibolite, which contrasts strongly on exposed surfaces with the white limestone. Very frequently, several of these blocks, which from their shape originally formed one continuous band, lie along the line of the strike of the limestone, at present separated from one another, the limestone having flowed into the interspaces as shown by the inward sweep of the foliation between the blocks. Sometimes the fragments bear evidence of having been drawn out or twisted by the disrupting force. Along the east shore, in Callahan and Rathbun bays, however, on concession VIII of Methuen, where the limestones form high cliffs descending precipitously into the water, several occurrences of these amphibolites are found in such a position that their origin is clearly seen. They occur as narrow dikes, usually not over a foot in width, cutting vertically through the bedding of the limestone, or transversely across it. In some cases, after cutting vertically through a number of beds, the dike will be abruptly twisted around into the plane of the bedding, and will then find its continuation in this plane as a string of separate blocks such as those referred to above. A sketch of this occurrence is shown in Figure 6. (See also Plates XXIX and XXX.)

There can, therefore, be no doubt concerning the origin of the amphibolites occurring in the crystalline limestones about Jack lake. They are basic dikes formed by intrusions of igneous material which cut through the limestones and were subsequently in many cases broken into separate blocks by great dynamic movements in the limestones themselves, which movements took place along the bedding planes of the rock. As blocks and elongated masses of fine-grained amphibolite, identical in character with that above described, are very commonly found in the limestone of other parts of the area, it is very prob-

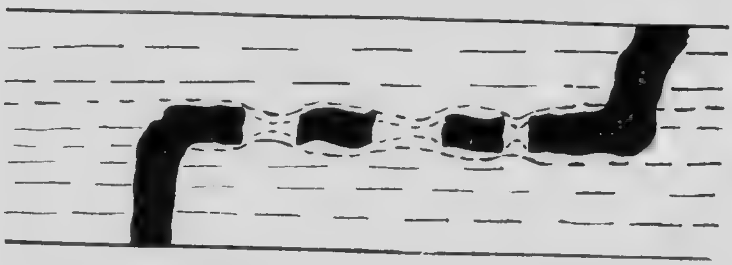
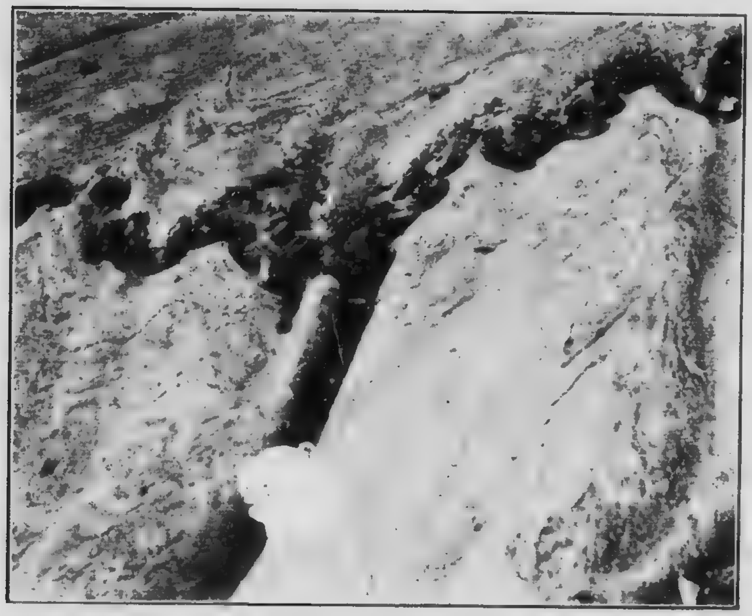


Fig. 6. Dike of amphibolite cutting across and between beds of crystalline. Jack lake, Methuen township, Ont.

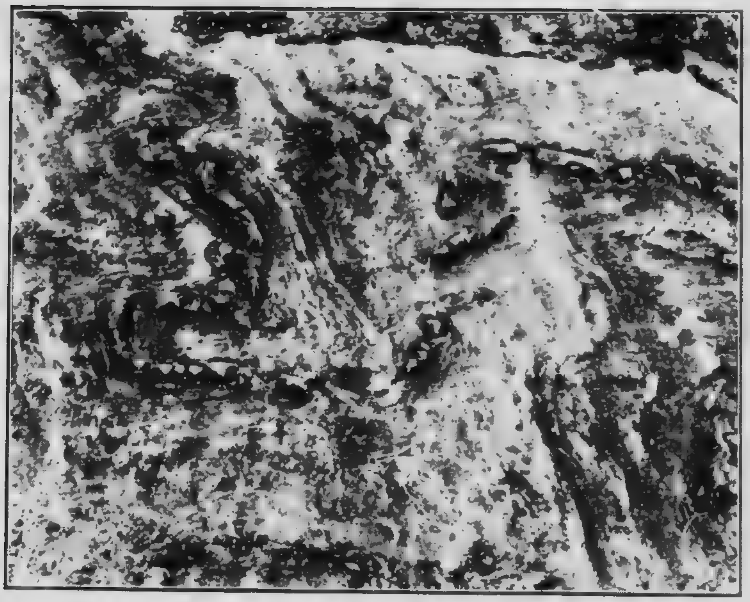
able that to them also a like origin is to be attributed. The amphibolite which forms these disjointed dikes in the limestones about Jack lake is very uniform in character and very fine in grain. In the hand specimens the foliation is barely perceptible, even with the closest scrutiny, but in thin sections of the rock under the microscope it is very distinct. The rock is seen under the microscope to be composed almost exclusively of hornblende, and plagioclase feldspar. (See Plate XXXI.) The hornblende is rather light green in colour in ordinary light. In polarized light it shows pleochroism in the following colours. $\mathfrak{a}$ = greenish-yellow, $\mathfrak{b}$ = green, $\mathfrak{c}$ = green. The absorption is $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. It is occasionally hypidiomorphic, but usually allotriomorphic in character, and occurs in an anastomosing meshwork of individuals, with a prevailing alignment in one direction which gives to the rock its foliation. It is not fibrous in character, as is so often the case in hornblendes of secondary origin. The plagioclase is clear and fresh in appearance, and rather basic in character. It usually shows polysynthetic twinning, but many of the individuals are untwinned. These probably, however,

PLATE XXIX.

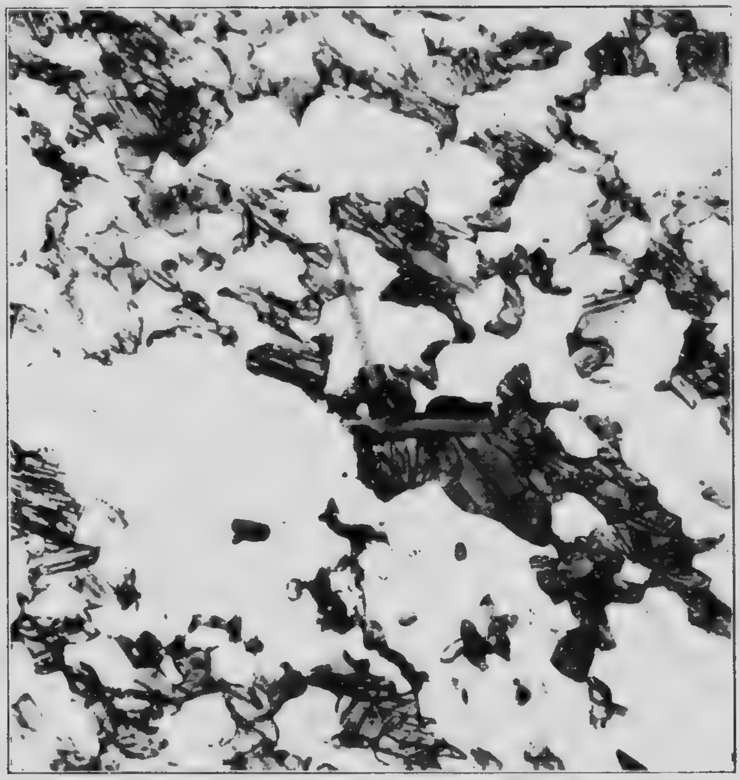


Dike of amphibolite interbedded with crystalline limestone. This dike has been folded with the limestone. It has also been stretched, and in places broken apart by the movement. Belmont lake, Belmont township, Ont.

Plate XXX.



Interbedded dike of amphibolite in crystalline limestone. Shows the intricate folding with frequent and pronounced breaks (autoclastic) in the more brittle dike. Belmont lake. Belmont township, Ont.



Microphotograph of amphibolite from a dike. Consists chiefly of plagioclase, hornblende, and biotite. Jack lake, Methuen township.
Ordinary light. Magnified 75 diameters.

do not represent a different feldspar, since, as will be shown in other similar amphibolites, where but a single species of plagioclase is present, a large proportion of it is frequently untwinned. This feldspar is allotriomorphic in character, and occurs as little grains between the hornblende individuals.

The only other constituents present in the rock are biotite, in very small amount, in scattered highly pleochroic individuals associated with hornblende; and very small amounts of iron ore (black in colour), pyrite, and sphene.

A chemical analysis of this rock is given on p. 108.

The structure is clearly that of a metamorphosed igneous rock. The original rock has been entirely recrystallized, but no trace of any of the primary minerals or of the original structure has survived. It is impossible to be certain of the precise character of the original dikes, but from the general nature and composition of the rock it is highly probable that they were diabases.

The alteration of dikes of typical diabase into amphibolite of precisely the character of that forming the Jack Lake occurrence has been described from Scourie in Scotland.[1] An amphibolite almost identical in character with that just described is found associated with the limestones on the south shore of Loon lake, in the township of Chandos. Here, across lots 11 to 20, on concessions VIII and IX, there are almost continuous exposures of thinly bedded crystalline limestones associated with these dark amphibolites. A specimen from lot 12, concession VIII, which was microscopically examined, proved to be practically identical in character with the rock from Loon lake. A little calcite, however, was present, while there was an absence of biotite. A few small grains of pyroxene, intimately associated with and passing into the hornblende, indicate the secondary nature of the latter.

Other occurrences of amphibolite, microscopically identical with these, are found interbanded with the crystalline dolomite on lot 19, concession VIII of Cardiff, and with the crystalline limestones on lot 38, concession VIII of Anstruther. Still another large occurrence of this rock is that found on the old Burleigh Road where it passes across lot 7, concession XV of Chandos. The rock here is exposed on the road for nearly a mile, and is

[1] J. J. H. Teall.—The Metamorphosis of Dolerite into Hornblende-schist. *Quart. Jour. of the Geol. Soc.*, May, 1885.

to the unaided eye either massive, or possessed only of a faint suggestion of foliation. Under the microscope, however, this rock is distinctly foliated, and bears a strong resemblance to the amphibolite dikes occurring at Jack lake and described above. It contains, however, proportionately less hornblende, and this mineral does not, therefore, form so continuous a meshwork in the rock. The hornblende and feldspar, as in the Jack Lake occurrence, make up almost the entire rock. The hornblende is rather deeper in colour and more bluish green than in the rock just mentioned, and has a more perfect crystalline form, with, in most cases, a distinct approach to idiomorphic development. The feldspar, as before, occurs in clear allotriomorphic grains, but is very seldom twinned. It is, however, in all probability, plagioclase, although a separation of the rock constituents by means of heavy solutions would be necessary to determine its precise character. In addition to these constituents the rock contains a small quantity of iron ore, a little quartz, and a little apatite. No biotite is present. In some specimens of this amphibolite from lot 7, concession XV of Chandos, there is present, in addition to the green monoclinic hornblende, a pale greenish-grey rhombic hornblende, probably anthophyllite. In the continuation of this same amphibolite mass on the northeast to Baudash lake, the rock in many places shows a more distinct foliation. This is probably to be attributed to the movements which accompanied and in part induced the metamorphism being here more extensive.

It thus seems highly probable, in view of their uniform character and their similarity in composition and structure to the amphibolite of Jack lake, that the amphibolites just described are deformed and altered basic igneous intrusives, which in some cases may have been lava flows.

One of the larger and more noteworthy occurrences of the coarser grained amphibolites, which is probably of igneous origin, is the remarkable mass which surrounds the circular area of limestone in which Duck lake in the centre of the township of Chandos, is situated. This mass, as has been shown on pages 19 and 31, is a great sheet of amphibolite lying between two limestones, one beneat hand one above it, the whole having a quaquaversal dip from a central point in Duck lake. The amphibolite making up this occurrence is, for the most part, coarse in grain, and possesses

a foliation, which, however, is indistinct, owing to the low angle of dip thus giving it a massive appearance closely resembling the diorite occurrences exposed in the northeastern corner of the same township. At its eastern extremity the mass becomes much finer in grain and more massive in character, thus resembling the fine-grained amphibolites from Jack lake described above. A specimen of the coarse-grained variety from lot 15 of Chandos, on the line between concessions XI and XII was examined under the microscope, and was found to be composed almost entirely of hornblende and plagioclase. The hornblende is rather deep green in colour and makes up about two-thirds of the rock. It forms a pretty continuous anastomosing meshwork through the rock, and consists of individuals which are allotriomorphic in outline, but which sometimes show an approach to a hypidiomorphic crystallization. The feldspar in allotriomorphic grains lies between the hornblendes, and, as is usual in the amphibolites of this area, is partly twinned and partly in untwinned individuals. A rather small amount of iron ore is present, occurring in irregular-shaped black grains associated with the hornblende. A few grains of pyrite, and a few small crystals of apatite are also present. There is no biotite, pyroxene or sphene, but the rock contains a not inconsiderable amount of quartz in clear grains, showing but little evidence of pressure. Another specimen from the same mass, collected on lot 9, on the line between concessions X and XI of Chandos, was found to be identical in character, but contained a small quantity of biotite, sphene, and calcite. A third specimen, from lot 10 on the same line, was also identical, but contained proportionately hornblende; while a specimen of the fine-grained variety, from lot 20, concession XI, at the eastern extremity of the mass, was found to differ from the others only in size of grain.

The presence of a small amount of quartz, which was noted in the thin sections, can be detected on the weathered surface of the rock, and can be seen, in places, to be fairly abundant. To the north of the area, on lots 13 and 15, dikes of black amphibolite, apparently connected with this Duck Lake mass, cut the limestone series. Interstratified sheets of the same rock are seen in many places on the road running between concessions XIII and XIV of Chandos, where it crosses lots 16 to 20. (See Plate XXXII.)

Another occurrence of amphibolite which is probably of igneous origin is that which has already been mentioned in describing the structure of the region. It is well exposed on lots 29 and 30 of concession I of Anstruther, where it is seen to come against the adjacent band of feather amphibolite, apparently with an intrusive contact. It is peculiar in that it is filled with an immense number of little separated and twisted strings of pegmatite. It is not certain whether the rock represents the product of the solidification of a mixed magma, or a mass of amphibolite thoroughly invaded by granitic material and reduced to a pasty condition, in which condition the rock moved into its present position. These same pegmatite strings also abound in the amphibolite surrounding Duck lake, in the township of Chandos, and described above, where its occurrence as traversed by the road between lots 15 and 16, concession XII of that township is treated of.

In addition to the amphibolites which have resulted from the alteration of igneous intrusions, there are in this area typical amphibolites, which have been produced by the alteration of limestone and other sedimentary rock. It is a remarkable fact, furthermore, that the amphibolites originating in these two very diverse manners often resemble one another so closely that it is impossible to tell them apart. So that in many cases, when the origin of a body of amphibolite is not discoverable from its field relations, it is impossible to determine whether it is an altered igneous or a body of altered sediment. This is the case with a large proportion of the occurrences of amphibolite embraced in the area covered by this report.

The development of typical amphibolite out of crystalline limestone—on a large scale—has already been described in that section of the report which deals with granites and their contact phenomena (see pp. 104 et seq.). In the cases there considered the alteration can be definitely proved to have taken place. There are, however, other occurrences not in direct contact with granite at the surface, but in highly metamorphosed districts, where the cause of the metamorphosis is undoubtedly the granite lying below and exerting its action upward, in which a similar change has apparently taken place, resulting in great bodies of amphibolite or pyroxene gneiss closely allied to these in composition, and which are often intimately associated with limestone in the field. In these cases, however, it is doubtful in how far

Sheet of massive amphibolite interstratified with crystalline limestone and feather amphibolite, lots 16 to 20, on road between concessions XIII and XIV, Chandos townsh[illegible], Ont

transfer of material from the granite to the limestone took place, and in how far the resulting rocks represent recrystallization of materials already present in the sedimentary deposits. One large occurrence of this nature is that which crosses the Hastings road on lots 31 and 57, and on which the village of Ormsby is situated. This is mapped as limestone and granular amphibolite. As will be seen on the Bancroft sheet, the rock strikes off to the southwest and sweeps around a large mass of diorite to the south, recrossing the road on lots 88 to 95, and passing off to the northeast into the township of Limerick. The occurrence consists of a finely banded dark amphibolite alternating with bands of limestone. The thickness of the bands of the rocks varies considerably, but over a large part of the area they are very narrow, each band being from one-eighth to one-fourth inch thick. (See Plate XXXIII.) The strike of the rock can thus be very clearly seen, and in many places displays a most complicated series of minute contortions, superinduced on the general folds of the region. (See Plate XXXIV, also Plates XXXV, and XXXVI). While the large bands of limestone are usually pure, and often very coarsely crystalline, the narrower bands are often very impure, as can be seen on the weathered surface, where the calcite has been dissolved away. The rock is excellently exposed on lot 34 of the Hastings road, and on a fresh fracture is seen to consist of thin alteration bands, which are respectively white and very dark grey, nearly black, in colour. In thin sections it is seen that the darker bands consist of a deep green pleochroic hornblende, with a pale green pyroxene of the same variety as the occurrence in the cut at Maxwells crossing, associated with feldspar; while the lighter coloured bands consist of calcite and feldspar, with but very little of the iron-magnesia constituents. The feldspar, like all the other minerals of the rock, is very clear and fresh. Some of it shows polysynthetic twinning, but a large part is untwinned, although it is very probable that the above is plagioclase. A small amount of sphene, in minute rounded grains, occurs scattered through the rock, and completes the list of constituents. The rock, while well banded, has a typical mosaic structure, and has been completely recrystallized.

To the north, on lot 57, the limestone bands disappear, and the amount of calcite in the rock becomes so small that the rock passes into an amphibolite, and is so mapped. In its development

the mass covers a great area, as shown on the map. The rock is composed of the same constituents as the amphibolite bands just described, but a little quartz is occasionally found in narrow strings running parallel to the foliation of the rock.

The amphibolite in this case might be characterized as a pyroxene hornblende granulite, or a very fine-grained pyroxene hornblende gneiss.

It seems very unlikely that in this case any transfusion of material from the granite could develop such a perfectly banded rock from a more or less massive limestone. The evidence is in favour of considering the rock as a sedimentary one in which there were original differences in composition; these laminæ of varying composition, when the rock became recrystallized by the heat from the underlying granite, by a process of diagenesis developed the various minerals of which it is now composed.

The large amount of hornblende and pyroxene in the rock would indicate that the original sediment was probably one of somewhat unusual character, and the presence of large stocks of gabbro and diorite in the immediate vicinity of the occurrences would suggest that the two had some genetic connexion. It is, for instance, quite possible that the amphibolite may be derived in part from the recrystallization of volcanic ashes thrown out from volcanic vents, of which the stocks referred to above represent the plutonic intrusions.

There are a number of other occurrences in the area which are allied to that just described, but in which the impure sedimentary material has recrystallized into a banded gneiss, which, however, contains biotite, with some pyroxene but with no hornblende. These rocks cannot be classed as amphibolites, although in the field they often resemble them, and will be considered in that section of the report which deals with the sedimentary gneisses.

Another variety of amphibolite concerning whose sedimentary origin there can be but little doubt, and which occurs in large areas in the district, is that which is referred to in the Bancroft sheet as feather amphibolite, a name which was suggested by its striking appearance in the field, and which was used to designate it during the mapping of the area. As a more detailed study of the rock failed to suggest any better name or one more descriptive of this peculiar variety of amphibolite, it has been here retained.

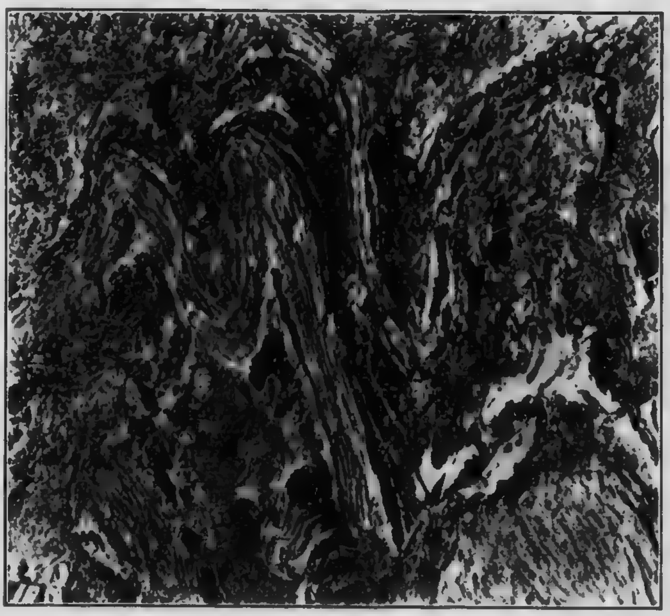
Plate XXXIII.

Interbanded crystalline limestone and granular amphibolite, showing differential weathering, lot 15, Hastings road, Faraday township, about ¼ mile north of Umfraville P.O.

PLATE XXXIV

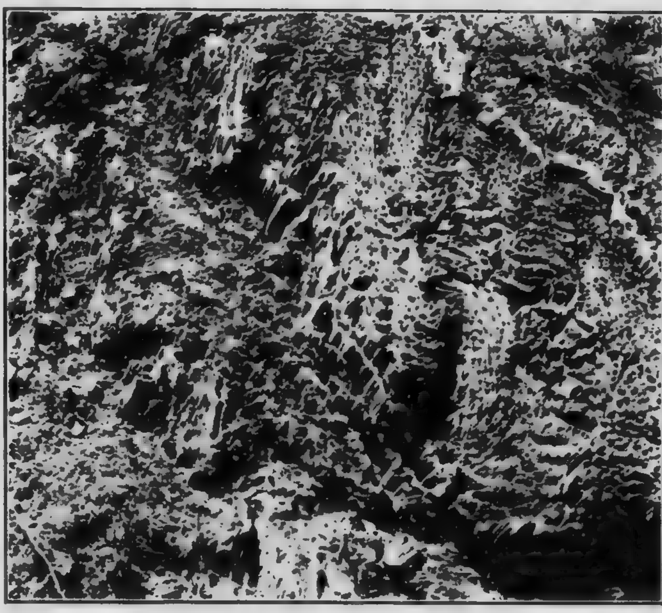
Interbanded crystalline limestone and granular amphibolite. Wellington road, lot 6, concession III, Chandos township, Ont

PLATE XXXV



Amphibolite, sharply folded, lot 32, concession A, Wollaston township, about one mile south of Ormsby.

PLATE XXXVI



Amphibolite, intricately and minutely folded, lot 32, concession A Wollaston township one mile south of Ormsby.

There are three chief occurrences of this rock—the first two very large and closely associated, while the third lies apart and is smaller in extent.

The first occurrence is that which is found in the northern portion of the township of Chandos, and from which a long belt runs down southeastern Anstruther, continuing to the south as far as the middle of Burleigh.

The second development lies chiefly in the southern half of the township of Dungannon. These two bodies of the rock lie in different parts of the same great area of limestone and must be considered as local developments of it.

The third occurrence runs down the length of the township of Lake, on concessions I and II, from lot 13 to lot 32. In addition to these there are a few small separate areas, as for instance two about the middle of the township of Wollaston, on concessions XI to XV, which, however, do not require any further mention here.

This feather amphibolite rarely occurs by itself, but is almost invariably found in thin bands alternating with similar layers of limestone, resembling in this respect that amphibolite just described on the Hastings road (page 165) The respective bands, usually less than an inch in thickness, are, however, not generally quite so sharply defined against one another as in that rock. The limestone, which is really a fine-grained marble, is sometimes white in colour, but more often is pale greyish or bluish, retaining traces of its original colour. On the edges of weathered specimens the structure of the rock is especially well seen, the calcite weathering out and showing the banded character of the rock in a striking manner. The composite rock is thus designated on the Bancroft sheet as limestone and feather amphibolite.

The distinctive character of the feather amphibolite is the form taken by the hornblende. This mineral has grown in the rock in the form of skeleton crystals, usually about an inch long and with a slender habit. They lie thickly scattered in the plane of the bedding or banding of the rock, intersecting one another and often forming a mat of crystals. (See Plate XXXVII, showing the appearance of a weathered surface of the rock broken parallel to the bedding plane. This specimen contains rather fewer of the hornblende crystals than usual.) Associated with these large hornblendes are in some cases similar crystals of pale green

pyroxene. These large crystals lie in a very fine groundmass which consists chiefly of feldspar. The rock thus, in mineralogical composition, is closely related to other varieties of amphibolite occurring in the area, but has a distinctive and persistent structure. It is associated with, and is evidently genetically connected with the limestones of the a[illegible] [illegible]des away into them.

Under the microscope the fe[illegible] [illegible]hibolite has a very characteristic appearance, and [illegible] from the various occurrences resemble each other c[illegible] T[illegible]t from the township of Lake, on lots 19 and 20 of [illegible] I, may be taken as a representative. When examin[illegible] [illegible]ctions the feathers are seen to consist of pale green hi[illegible] [illegible] hornblende, long and narrow in shape [illegible] rounded grains of the colourless mineral [illegible] groundmass. They present a filigree-like appear[illegible], an[illegible] [illegible]idently grown in the substance of the rock as recrystalli[illegible] went forward, and as the andalusite crystals devel[illegible] in th[illegible] [illegible] of a contact zone. (See Plate XXXVIII.) Associated with these are, in some specimens, a few large crystals of sphene, with a few inclusions of black iron ore having a similar filigree habit, as well as occasionally a large individual of biotite. The large individuals lie in a very fine-grained mosaic of clear colourless grains of nearly uniform size. These are allotriomorphic and in this way give the groundmass the *pflaster* structure seen in recrystallized sediments. These grains are feldspar, as shown by their biaxial character and general optical properties. These feldspar grains are usually untwinned, but some show polysynthetic twinning. Whether the feldspar is all plagioclase or whether some orthoclase is present can only be determined by a chemical analysis of the rock. Through this growth there are also some coarsely crystalline grains of calcite often in groups or strings. The limestone bands alternating with this feather amphibolite are seen under the microscope to consist of grains of calcite associated with others of feldspar, and a few flakes of biotite. The rock has a distinct banding, the several minerals being relatively more abundant in different bands, but there is no flattening of the individual grains.

The feather amphibolite of the Chandos-Burleigh area is very similar in character. Specimens of it from two places have been examined microscopically. The first of these was from lot 2,

Weathered surface of feather amphibolite, township of Wollaston

PLATE XXXVIII

Microphotograph of feather amphibolite, lot 19, concession I, Lake township. Ordinary light. Magnified 25 diameters.

concession IX of Chandos, and the second from lot 29, concession V of Anstruther. The only point in which they differ from the rock above described is in the fact that there are some feathers of a pale green malacolite as well as of hornblende. In the Anstruther rock, while much of the feldspar in the mosaic shows the polysynthetic twinning of plagioclase, some of it shows the cross-hatched twinning of microcline, and is, therefore, a potash feldspar. This rock also apparently contains a little quartz, as well as a small amount of a mineral which has the characters of scapolite.

In the Dungannon area, specimens from lot 25, concession V, and from lot 16, concession VII, were examined microscopically and were also found to possess essentially the same character as the rock just described. The feathers, which are beautifully developed, consist of hornblende, and with them is more or less black iron ore in large grains, which sometimes also show the filigree structure. The mosaic groundmass consists principally of feldspar—often showing polysynthetic twinning—but there is also a certain amount of quartz present in it, as shown by its uniaxial and positive character.

The sedimentary origin of the feather amphibolite is most clearly shown in the limestone area of the southwest corner of the township of Lake, on the Deer lake and Vansickle roads. Here about the limit of the Bancroft sheet and just to the south, on lot 2, concession II, and lot 1, concession I of Lake, the limestone is much less altered than it is in the more northern portions of the area, and is in many places blue in colour. In the comparatively unaltered blue limestone there are thin hard bands which stand out on the weathered surface. The appearance is exactly that seen when the feather amphibolite with its thin alternating bands of limestone is weathered. These harder bands are clearly produced by the alteration of some laminæ in the original rock, in which the limestone was very impure through the admixture with it of some siliceous sediment. When examined under the microscope, some of the bands are seen to be essentially the same as feather amphibolite, in fact, little feathers can be seen on the weathered surface in some specimens. These feathers in some cases are hornblende, with skeleton crystals of calcite and magnetite, as in a specimen from lot 1, concession I of Lake. The groundmass in this case is very fine and shows a well marked

foliation. It consists of quartz and feldspar (plagioclase in part at least) with little scales of chlorite. The rock would, under more intense metamorphosis, undoubtedly develop into a true feather amphibolite. In other specimens from the same lot the feathers in the hard bands are biotite, and the rock thus belongs to the biotite paragneisses rather than to the amphibolites. These biotite-bearing rocks will be referred to again in that section of the report dealing with the sedimentary gneisses.

Still another occurrence, which from its position must be considered as the product of the extreme alteration of limestone by a granitic magma, and which is designated on the map as amphibolite, occurs along the north shore of Fishtail lake, in the township of Harcourt. As will be seen by consulting the Haliburton sheet, this mass lies in the granite-gneiss which forms the northern part of the area, between two long narrow masses of limestone and on their strike. It is apparently a small mass detached from them, and very highly altered by the granitic magma which envelops it.

The amphibolite is a dark basic variety, consisting largely of anthophyllite and garnet, associated with cordierite and subordinate amounts of quartz, biotite, iron ore, and rutile. The anthophyllite is very abundant, occurring in groups or sheaves of long narrow individuals, often curved and without proper crystallographic terminations. Under the microscope the anthophyllite is seen to contain a few small inclusions of black iron ore and of biotite. The mineral has a bright lustre and possesses that delicate clove-brown colour which caused Schumacher, who first described this mineral, to give to it the name anthophyllite. (See Plate XXXIX.)

The mineral has a perfect cleavage, parallel to the prism and also to the brachypinacoid. Two cleavage fragments were selected and measured on a reflecting goniometer. The average of four measurements gave the cleavage angle as 54° 41′. In thin sections the mineral shows the lozenge-shape characteristic of the hornblendes, and in sections in the prismatic zone always presents a parallel extinction. The mineral is negative and the pleochroism, using Idding's notation, is as follows:—

X= pale yellow; Y= brownish yellow; Z= clove colour or grey. The absorption is $Z > Y > X$.

PLATE XXXIX.

Microphotograph of amphibolite. Shows gedrite associated with biotite, cordierite, iron ore, and garnet. Lot 11, concession IX, Harcourt township. Ordinary light. Magnified 25 diameters.

The cordierite occurs in colourless allotriomorphic individuals, which are slightly turbid when contrasted with the quartz, which they otherwise resemble. The mineral is biaxial and displays itself no pleochroism, but shows in a striking manner the little pleochroic halos so commonly found in this mineral when it occurs as a constituent of metamorphic rocks. These halos, which are quite numerous, change from deep yellow to colourless as the section is rotated, each halo having in its centre a minute, colourless, rounded crystal with high index of refraction and high double refraction. The cordierite also shows in places the twin lamellæ frequently observed in this species, and is occasionally somewhat altered, especially along the cleavage lines, into the cryptocrystalline aggregate of some micaceous mineral. It occasionally contains the little bundles of minute sillimanite crystals which are so characteristic as inclusions in cordierite.

This is, so far as can be ascertained, the first occurrence of cordierite which has been found in Canada.

In order to obtain material for analysis a hand specimen of the amphibolite was crushed sufficiently fine to pass through a sieve of 70 meshes to the inch. To free the powdered material from the finest dust, it was then placed on a sieve of 100 meshes to the inch, and that portion which passed through the latter sieve was discarded. The material was then submitted to the action of a Wetherill magnetic separator provided with two pair of magnets, the first of which were placed ¼ inch apart, while the second set were $\frac{5}{16}$ inch apart. It was found that 0·8 amperes removed the magnetite and a little ilmenite, while with a current of 3 amperes the rest of the ilmenite, the rutile, some garnet, and some anthophyllite were withdrawn. The current was then raised to 15 amperes, which removed the remainder of the anthophyllite and the garnet, with most of the biotite, the tailings consisting of cordierite, quartz, and a little biotite. In order to complete the separation recourse was had to heavy solutions. By means of the Klein solution the garnet was removed. Iodide of methylene was then employed, which when diluted with a few drops of benzol was of such specific gravity that the biotite floated, while the anthophyllite sank. This latter, however, was seen when examined under the microscope to still contain a few composite grains of feldspar or garnet, with a little black iron ore. The powder was accordingly placed under a

lens of low power and the foreign material removed by means of a fine needle. Perfectly pure anthophyllite was thus secured.

This material was then analysed by Prof. N. Norton Evans, all the determinations being made in duplicate, with the exception of those of water and the alkalis. The mean of the analyses of the air dried powder is given below. An analysis of the original gedrite from the valley of Héas, by Pisani, is presented for purposes of comparison.

	Gedrite. Township of Harcourt, Ont. (Evans)		Gedrite. Valley of Héas, near Gèdres. (Pisani.)
		Ratio	
SiO_2	44·32	0·734	43·58
Al_2O_3	16·04	0·156	17·07
Fe_2O_3	2·80	0·017	.....
FeO	16·88	0·235	15·96
MnO	0·09	0·001	.....
CaO	0·77	0·013	0·75
MgO	15·95	0·395	18·30
H_2O	1·31	0·073	3·92
K_2O and Na_2O	1·86	0·024	. .
	100·02		99·58

The ratio of R O: SiO_2 is 0·741: 0·734, or very nearly 1:1; and the ratio of R_2O_3: SiO_2 is 0·173: 0·734, or almost 1:4. This gives a formula corresponding to that suggested by Rammelsberg, namely, 4 $RSiO_3 + Al_2O_3$ where R = Mg, Fe, H_2.

From this analysis, as well as from its negative character, it will be seen that the mineral belongs to the aluminous variety of anthophyllite known as gedrite, this being, as above mentioned, as far as can be ascertained, the first occurrence of this variety reported from North America. The close similarity in composition of the mineral from Harcourt and the original gedrite from the Valley of Héas, near Gèdres, in France, will be noted.[1]

[1] Bancroft, J. A., and Evans, N. N.—On the occurrence of Gedrite in Canada. Am. Jour. of Science, Vol. XXV, June, 1908, pp. 509-512.

GNEISSES OF SEDIMENTARY ORIGIN (PARAGNEISSES), QUARTZITES, AND ARKOSES.

In addition to those gneisses which are varietal phases of granite and which have already been described as gneissic granites in the section of this report treating of this group of rocks (pp. 51 et seq.), there are certain gneisses, different in character, which in many cases at least are of sedimentary origin, and which probably in all cases contain sedimentary material. Gneisses of this class have also been recognized in other parts of the Laurentian area in Canada.[1] Some of these sedimentary gneisses or paragneisses represent alterations of more or less highly argillaceous sediments. Others are rich in quartz and mark transitions to true quartzites, which latter are also found in several parts of the area, and which represent, in some cases at least, highly altered sandstones. Some of these quartzites are rich in feldspar and represent the alteration products of arkoses.

On the Bancroft sheet these rocks are distinguished by three separate colours, namely, those which represent:—

(a) "Gneisses, principally altered sedimentary material or quartzite;"

(b) "Clay-stones, often siliceous or calcareous, with admixture of volcanic material;"

(c) "Conglomerate, sandstones, and arkoses."

The conglomerates are described in another portion of this report (see pp. 39 et seq.) and will not be again referred to here. The other rocks of this group, however, will be considered together in this chapter on account of their close genetic relations.

These rocks find their chief development in three great occurrences, which will be considered in succession. Reference will then be made to certain smaller areas which merit special consideration.

(1.) Those in the townships of Tudor and Lake which are intimately associated with comparatively unaltered limestones,

[1] Adams, F. D.—Geology of a portion of the Laurentian country to the north of the Island of Montreal. Ann. Rep. of the Geological Survey of Canada. Vol. viii. 1895.

and which are mapped as altered clay-stones, and in part where the association with the limestones is too intimate to permit of separate mapping (as about Millbridge), are incuded with these in the areas designated by the deep blue colour.

(2.) The large development which is shown on that portion of the map where the townships of Chandos, Anstruther, Burleigh, and Methuen meet, and which continues almost without interruption along the southern margin of the first named township to its southeastern corner.

(3.) The gneisses occurring about the borders of the series of batholiths in the townships of Anstruther and Cardiff.

PARAGNEISSES OF THE TOWNSHIPS OF TUDOR AND LAKE.

Between Millbridge station, on the Central Ontario railway, and the Millbridge post-office, which lies rather less than two miles farther west, both being situated in the township of Tudor, the blue limestone is excellently exposed. It is well-bedded, heavier beds alternating with thin beds, which are often laminated. These beds are not often identical in character; some of them are more distinctly blue in colour and effervesce readily when a drop of diluted acid is placed on the surface of the rock; others are greyer in colour and give a distinct effervescence only when powdered. The lamination undoubtedly represents the original bedding of the rock, and while the rock in many places is much contorted, the limestone still retains its blue colour, showing that the alteration has not been nearly so intense as in the case of the white limestones of other parts of the area, where metamorphism has entirely discharged the colour, producing at the same time a certain coarseness in grain.

A qualitative chemical examination shows that the blue beds are limestones, all more or less impure, and that the grey beds are much more impure varieties of the same rock. The proportion of magnesia present does not seem in any case sufficient to constitute the rock a dolomite, although in the absence of a quantitative examination, the actual proportion of this base present remains uncertain.

A microscopic examination of a series of thin sections of specimens of the various varieties of the rock, shows that all stages of the continuous transition from a limestone containing only a few flakes of brown mica to a micaceous paragneiss

(*pflastergneiss*) are represented. The latter constitutes the hardest grey beds and holds scarcely any calcite, but contains, on the other hand, much biotite, in the form of individuals which usually possess a somewhat frayed outline and lie in a fine-grained base of colourless untwinned grains, some of which are quartz, but some, and perhaps the majority, are probably orthoclase. Pyrrhotite also occurs scattered through the rock, but no trace of any other magnesia constituent, except the biotite, was found in any of the slides, nor was any other mica but biotite present. In most of the sections minute rutile crystals, identical with those so commonly found in clay slate, were present.

The occurrence evidently represents a great body of limestone, made up of an alternation of beds which vary greatly in the amount of impurity (silt or mud) which they contain, and which, under the relatively slight metamorphism which this portion of the area has undergone, has suffered a diagenetic alteration into the varieties of limestone and paragneiss above described. In the movements to which the strata have been subjected, the purer limestone beds curiously enough are seen to have been less resistant than the more impure gneissic beds, for they can be seen on the weathered surface to have been torn apart, while the gneissic beds flow in between the separated fragments. A considerable amount of local solution and redeposition has also taken place, as shown by the presence of a coarse-grained development of the gneissic bands along certain irregular lines often running transverse to the bedding. This area of blue limestone, with its pure and impure bands, under a more intense metamorphism, such as that to which the more northerly portion of the district has been subjected, would develop into a series of coarsely crystalline white limestones, with interstratified bands of the rusty biotite-bearing gneisses which are so extensively exposed elsewhere in the district, and which are so commonly found in all developments of the Grenville series, in Canada. Such an occurrence as this therefore represents a series of rocks petrographically identical with the Grenville series, in a less altered form.

In the southwestern portion of the adjacent township of Lake, to the west of the blue limestone area just described, there is a further development of similar fine-grained gneissic rocks. This latter is coloured on the Bancroft sheet as "Clay-stones (often

siliceous and calcareous) with admixture of volcanic material." To the south these rocks pass on the strike into limestone, and to the north and west into a series of rocks resembling amphibolite, and which are so coloured, the latter rocks having associated with them, in certain places, beds of quartzite. All these rocks are now completely recrystallized. Some of these are undoubtedly paragneisses formed by the alteration of argillaceous sediments. Others, again, are undoubtedly altered siliceous sandstones. The origin of others it is impossible now to determine, but there are in the series numerous intercalated bands of volcanic rocks which have already been described as orthophyres. It is surmised, from the appearance of many of those bands whose genetic relations are doubtful, that they represent altered volcanic ashes, which have become mingled with more or less sedimentary material of the ordinary types.

The rocks present many varieties, and a satisfactory study of them would require the expenditure of much time, and would be incomplete without the aid of chemical analysis. A microscopic examination has, however, been made of some of the more characteristic of the rocks represented in this interesting group.

Whetstone, township of Lake, lot 6, concession III.—This rock is dark grey in colour and occurs in large exposures on the east side of Mud Turtle lake. It is thinly bedded, splitting up into long, narrow, slab-like fragments under the influence of the weather, and is found to make good whetstones. It is very fine in grain, and has a somewhat felsitic appearance when seen on fractures transverse to the bedding of the rock. Some bands contain small rhombohedral crystals of a carbonate, which weather out on exposed surfaces. Under the microscope the rock is exceedingly fine in grain, requiring a high power to resolve it. It possesses a distinct foliation, and consists of a fine-grained base, through which are distributed somewhat larger, irregular-shaped individuals of biotite. This base is made up of clear, colourless grains, which are apparently chiefly untwinned feldspar, although quartz is also present, as well as an immense number of minute flakes of muscovite, with a little black iron ore, and a little apatite, as accessory constituents. The rock is probably derived from the alteration of an impure argillaceous sediment.

A determination of the amount of silica present in the rock was made by Dr. Milton L. Hersey. This was found to be 54·66 per cent, which is about the average percentage present in a clay slate.

On the opposite shore of the lake, on the same lot, there is a similar altered mud rock, which possesses an additional feature of interest in that it holds in great numbers the little geniculated rutile crystals so often met with in slates and shales.

Still another variety of the rock, closely related to that above described, is exposed on the east side of Mud Turtle lake, near the northern end of lot 8, concession III. This contains, scattered thickly through it, little rhombohedra of a rusty weathering carbonate. It also shows in immense numbers the minute geniculated crystals above referred to, as well as many small individuals of tourmaline.

Biotite Paragneiss, township of Lake, lot 2, concession III. This rock is dark grey in colour, and, while fine in grain, is coarser than the whetstone just described. It occurs in well defined bands which, there is every reason to believe, represent beds, and furthermore shows distinct false bedding (cross lamination), the beds showing this structure being about 6 inches in thickness. Under the microscope the rock is seen to be holocrystalline, and to possess a somewhat confused foliated structure. It is made up of biotite and black iron ore, with small amounts of muscovite, epidote, zoisite, and apatite, which minerals together make up about fifty per cent of the rock, the other half consisting of clear transparent, and colourless grains of orthoclase, no quartz being observed. None of these constituents have any marked approximation to good crystalline form, having been produced by recrystallization and the action of metamorphic processes. The rock is a paragneiss, produced by the alteration of some sedimentary material. An examination of large weathered surfaces suggests very strongly that there has been a large admixture of volcanic material with the ordinary epiclastic sediment.

Paragneiss, township of Methuen, concession III, road between lots 3 and 4.—A fine-grained grey rock showing a rather distinct foliation. Under the microscope it is seen to be composed of an aggregate of clear colourless grains, which are for the most part quartz, although there is probably some orthoclase associated with them. These form an aggregate, giving to the rock a pave-

ment, or mosaic structure. This varies somewhat in size of grain in different bands. Through this are sparingly distributed—emphasizing the foliation—larger skeleton crystals of muscovite, biotite, and calcite, with small irregularly rounded grains of black iron ore, and a few crystals of deep bluish-black tourmaline. This is a highly siliceous paragneiss, being undoubtedly an altered sediment. It is typical of the lighter coloured bands found in this series of rocks, which strike across concessions II and III on lot 3 of this township. It is interstratified with very dark coloured bands, which resemble it in microscopic character, but which are rich in biotite and hornblende, forming transitions into amphibolite.

In association with the paragneisses above described, there are two occurrences, which, from their appearance in the field and their petrographical character, are believed to represent highly altered clastic sediments of the nature of sandstones. The first of these can be traced from lot 17 of concession II of the township of Lake, northward along the west side of Lake Tangamong to lot 23 of the same concession of this township, a distance of rather more than two miles. This rock is well exposed at the narrows of Trout lake, on lot 30, where the band has a width of about 600 feet, and stands nearly vertical. Its character is as follows:—

Pyroxenic Sandstone, narrows of Trout lake, township of Lake, lot 20, concession II.—The rock is thinly bedded, consisting of alternate somewhat thicker pale grey and somewhat thinner nearly black layers. These layers are usually only a fraction of an inch in thickness. The lighter coloured layers, however, in some cases attain a maximum thickness of 6 inches. The beds, which as above mentioned are vertical, when seen from a distance present the appearance of the leaves of a gigantic book. The lighter coloured layers are granular in appearance, and under the microscope are seen to be composed essentially of quartz, pyroxene, and hornblende, the two latter minerals together making up about one-half the rock. The quartz occurs in perfectly clear grains, which are often more or less rounded in shape, having the form of sand grains. The rock, however, has been largely recrystallized, and such forms are not very common. Although the pyroxene and hornblende are colourless and non-pleochroic, occurring usually in allotriomorphic grains scattered

through the rock, in some cases they display an imperfect crystalline form. As accessory constituents, orthoclase, plagioclase, calcite, biotite, and tourmaline are found, all in small amount. The dark bands, which are thinner and less numerous than the lighter coloured ones, owe their colour to the presence in them of a large amount of deep brown pleochroic biotite, which in the lighter coloured bands is present merely as an accessory constituent. In these dark bands the proportion of pyroxene and hornblende is also relatively greater, and the tourmaline, which is present only in small amount, instead of occurring in little greenish-grey grains, is found in well-developed crystals, having a brown colour. This band of rock is evidently of sedimentary origin, and in its original form was probably a sand deposit containing dolomitic material. A silica determination made on a specimen from a light coloured band showed this to contain 59·06 per cent.

On the west side of this band, as exposed on the south shore of Trout lake, the rock loses the dark bands, and shows on the surface of fracture numerous little scales of muscovite, and on the weathered surface displays occasional small individuals of feldspar, rather coarser in grain than the rest of the rock, and which have the form of phenocrysts partly destroyed by metamorphism. Under the microscope the rock is seen to be composed of quartz and orthoclase, the former apparently preponderating, together with much muscovite in little crystals, lying parallel to the bedding of the rock. The apparent phenocrysts are individuals of an acid plagioclase, a feldspar which is apparently absent from the groundmass of the rock - and are wanting in crystalline outline. A little iron ore and tourmaline occur as accessory constituents. The rock has evidently suffered an almost complete recrystallization, but is probably an extremely altered arkose.

Another rock whose appearance suggests that it may originally have been an arkose, is that which occurs on lot 20 on the northwest line of the township of Lake, and is on the map classed with the amphibolites. This rock is now, however, completely recrystallized, so that its original character is entirely obliterated.

The other occurrence is the rock which forms the southern and western shores of Oak lake, in the southern portion of the township of Methuen.

Arkose, Oak lake, township of Methuen. This overlies the limestone of Oak lake, and belongs to the same series as that which furnishes the paragneiss described on pages 177 and 178, resembling in appearance that from the line between lots 3 and 4 of concession III of Methuen, being, however, practically free from iron-magnesia constituents. It is well exposed on the shore of the lake, about the middle of lot 3, concession V. Here, the rock, although on first examination resembling a fine-grained granite, on closer examination seems to be a sedimentary rock composed largely of granitic material, a sort of fine-grained arkose. It possesses a well marked bedded appearance, unlike the granite or gneissic granite found elsewhere in this region, and when carefully examined on the weathered surface, these bands are seen in some cases to be more quartzose than in other cases, some bands being, in fact, composed of nearly pure quartz. Most of the rock is, however, evidently highly feldspathic. A silica determination, made on a hand specimen of the rock, yielded 74·62 per cent of silica, which is the percentage present in an acid granite. Under the microscope it is seen to be composed essentially of quartz, orthoclase, microcline, and plagioclase, the first mentioned constituent being the most abundant and the orthoclase preponderating among the feldspars. The only other constituent present is a little magnetite, in irregularly scattered grains; and a few flakes of muscovite are also seen.

The banded character above referred to is distinctly seen, the bands presenting a variation in size of grain, as well as in relative proportion of the constituent minerals. Small irregular-shaped individuals of the feldspars, somewhat larger in size than the ordinary constituent minerals of the rock, and often more or less twisted, are occasionally seen. In this respect the rock resembles one of the specimens above described from Trout lake. The microscopic study of the rock bears out the conclusion drawn from the study of the rock in the field, namely, that it represents a feldspathic sedimentary deposit of the nature of an arkose.

PARAGNEISSES OF CHANDOS, ANSTRUTHER, BURLEIGH, AND METHUEN.

This is the largest development of these rocks in the area. The varieties composing it consist of gneisses which almost invariably weather to a rusty colour, as is so often the case with similar rocks in other parts of the Laurentians of Canada. In some exposures the whole body of the rock partakes of this rusty weathering character; in others certain bands alone weather in this manner; while in others this peculiar weathering is absent. These peculiar gneisses are well exposed about the village of Apsley, the development here being typical and the rocks presenting evidence of their sedimentary origin in their well-bedded character, and also in the fact that they hold beds of interstratified limestone toward the western margin of the occurrence, where traversed by the road running west from the village of Apsley. This development of gneisses can be followed to the north into concession V of Anstruther, where it becomes replaced by, and apparently passes into the amphibolite, with the exception of two small areas on concession VI of this township, which are surrounded by amphibolite, as shown on the Bancroft sheet.

To the south of Apsley the rock is well exposed on the Jack Lake road, but in the Gore of Chandos, and northern Anstruther, the band swings round and bends back upon itself, crossing from the latter township into Chandos, where it is well seen on the Wellington road; and thence traversing this township in a northeasterly direction it reaches the shore of Loon lake. Along this latter portion of its course the series is much fractured and contorted, the lines of fracture being filled with strings of quartz, which are probably genetically connected with the pegmatite dikes which here in increasing numbers cut through it. These in their turn are connected with the Loon Lake granite mass, which at this place breaks through and cuts off the series, and which about its margin is filled with fragments of it, and shows in places very marked endomorphic alteration.

These paragneisses vary considerably in character from place to place. The typical very rusty weathering variety is excellently exposed on lot 32, concession I of Anstruther, at the point where Eels creek crosses the Apsley road. Thin sections of this rock, when examined under the microscope, show that the rock

possesses a typical pavement structure, and consists of an almost uniform mixture of biotite with orthoclase, plagioclase, and quartz. The biotite is in the form of small irregular-shaped individuals having the form of laths, when cut in the direction of the vertical axis, while the other constituents have an allotriomorphic development. There are also a few small grains of a yellow sulphide of iron, irregular in shape, but rather larger than the other constituents of the rock, and to which is due the rusty weathering of the rock. Some of the potash feldspar shows faint microcline twinning. It is impossible, without a chemical analysis of this rock, to determine the relative abundance of the three colourless constituents which are present. A chemical study of this series of highly altered rocks would be of much interest, as affording a knowledge of their quantitative chemical composition, which would probably throw much light on the nature of the original material from which these rocks were derived.

PARAGNEISSES AROUND THE BORDER OF THE BATHOLITHS OF THE TOWNSHIPS OF ANSTRUTHER AND CARDIFF.

Around the great granite batholith which occupies the chief part of the township of Anstruther, there is, except on the southeast side, where the batholith is bounded by a fault, a zone of gneisses of a peculiar type and of more or less varying character. This gneiss at one time entirely encircled the batholith in question, for along the southern margin, where the batholith is not completely closed in, the granite of the batholith is filled with inclusions of the gneiss, while a large isolated mass of it occurs on the west side of Deer lake. These inclusions evidently represent the southern portion of the peripheral border of paragneisses in a disrupted condition. The evidence goes to show that this belt of gneisses represents the result of a partial solution of the surrounding limestones, perhaps mixed with certain highly altered pelitic sediments, by the granite magma of the batholith. About the two more northerly batholiths of this linear series gneisses of this class also occur. That which is so extensively exposed on the side of the first of these along the southeast shore of Eels lake resembles a foliated hornstone in character, while that about the most northerly of the batholiths is extremely shattered and broken by the invading granite, and is represented for the most part by a coarser grained grey gneiss, often rusty weathering, and

associated in places with a little limestone. Everywhere about these batholiths, dikes, strings and flammen of pegmatite abound, and around the most northerly of the batholiths, in north-east Cardiff and about Centre lake, this intruded material is so abundant that it constitutes a large part of the complex.

The general distribution and character of the gneisses of this third area has already been considered in that portion of the report dealing with the contact phenomena of the granites (pp. 51 et seq.). Petrographical descriptions, however, of a few typical varieties of these gneisses will be given here.

Catchecoma Gneiss, Cavendish, lot 23, concession V (near line of VI).—Exposures of this gneiss in its typical development are seen on the east side of Lake Catchecoma, in concession V of this township. As already stated, it has in all probability been produced by the alteration and absorption of the limestone by the granite of the intruded batholith. It is of medium grain, grey in colour, foliated and more or less distinctly banded. The bands are narrow, being marked by slight differences in shade of the alternating bands. Some of these latter hold strings of coccolite and epidote. It is traversed by little strings and knots of basic granitic material, composed of quartz, iron ore, feldspar, etc.

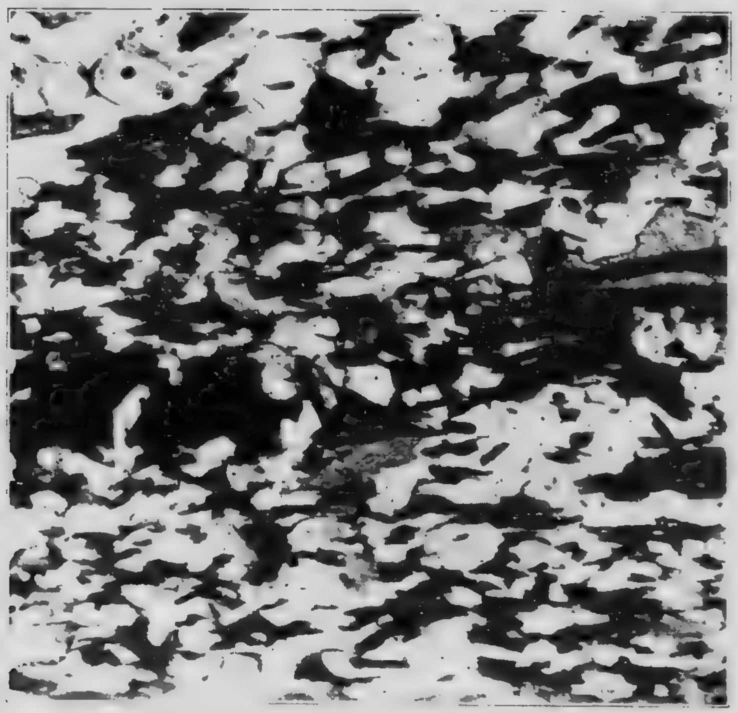
Under the microscope the rock is seen to consist chiefly of feldspar and hornblende. The feldspar is usually very clear and fresh. It is in part plagioclase, but a considerable amount of untwinned feldspar, probably orthoclase, is also present. The hornblende is very deep green in colour and strongly pleochroic, being similar in character to that found in the pyroxene gneisses which have been produced by the alteration of limestone under the action of granite intrusions (pp. 99 et seq.). Scapolite is also present in considerable amount, as well as magnetite, sphene, apatite and, a little biotite. No quartz could be found in the sections. The rock is, therefore, a dioritic gneiss or feldspathic amphibolite, having a distinct resemblance in many particulars to rocks which elsewhere in the area are formed by the action of granite intrusions upon the limestones. The minerals are allotriomorphic and the rock has a distinct foliation.

Catchecoma Gneiss, township of Harvey, lot 32, concession III. This rock is from Depot point, near the southern extremity of Mississagua lake. It very closely resembles in appearance the

rock just described from the township of Cavendish. Under the microscope it is seen to be almost identical in character with this latter. It contains, however, no scapolite, but holds in addition to the other minerals present in the Cavendish rock a few grains of calcite, pyroxene, and epidote, and a little quartz. The pyroxene is intimately associated with the hornblende and is apparently in the act of altering into it, while the epidote occurs chiefly in the form of a border around the pyroxene individuals.

Paragneiss, Cardiff, lot 7, concession III.—A great belt of gneisses, associated with limestone and amphibolite, sweeps around the eastern side of the nearly circular batholith, and is traversed by the town line of Monmouth and Cardiff. These gneisses are excellently exposed along the southeast shore of Eels lake. The rock here is for the most part fine in grain and dark in colour, holding in many places lumps of red garnet, in some cases as much as 2 inches in in diameter. A characteristic variety of this rock occurs on lot 7, concession III. This is very fine in grain, so that on fractures transverse to the foliation it possesses a felsitic appearance. It has a well marked foliated structure, and the weathered surface often shows a peculiar pitted character, the origin of which it is difficult to ascertain, as the pits do not correspond to any observable irregularity in the composition of the rock. Under the microscope the rock is very fine-grained, with a perfect foliation. It is made up chiefly of biotite, quartz, orthoclase, and plagioclase, with numerous folia of a black opaque mineral, which are associated with and run parallel to the individuals of biotite. In addition to these minerals a very small amount of a pale green hornblende, decomposing into calcite, is present in the rock, as well as a few small grains of tourmaline. The opaque black mineral referred to, when examined carefully by reflected light, is seen to be composed of two minerals very finely interleaved with one another, one of these being of a dead black colour and showing no crystal form, while the other is greyish black and crystalline with a bright metallic lustre. When an uncovered section of the rock is warmed with concentrated hydrochloric acid, the acid extracts a certain amount of iron, but the black leaves do not disappear, nor are they destroyed when the section is heated to redness. When, however, the rock is powdered and subjected to repeated treatment with

PLATE XL



Microphotograph of paragneiss (fine-grained biotite-gneiss with graphite).
Eels lake, lot 7, concession III, Cardiff township
Ordinary light. Magnified 30 diameters

hydrofluoric acid, the black mineral remains as a residue, and when this residue is heated to redness for some time the black colour disappears, each of the grains which was originally black assuming a pale yellow colour. It is thus evident that one of the black minerals in these opaque leaves is a carbonaceous material, probably graphite, while the other is an iron ore, probably magnetite. The two minerals evidently have a close genetic relation. (See Plate XI.)

PARAGNEISSES AND ALLIED ROCKS FROM OTHER PARTS OF THE AREA.

Rusty weathering gneisses, clearly representing sedimentary material in a highly altered condition, are found typically developed in a number of places in the western portion of the Haliburton sheet.

One of these is a short distance to the south of the village of Minden, near the point where the four townships of Lutterworth, Anson, Minden, and Snowdon meet. Here there is a cliff forming a rather remarkable topographical feature and consisting of a well-stratified series of graphitic limestones alternating with the rusty weathering gneisses. The gneiss, like the limestone, holds small sparsely disseminated flakes of graphite, and is almost white on a fresh surface of fracture. Under the microscope the rock is seen to be composed of orthoclase, microcline, plagioclase, and quartz, with biotite and graphite as subordinate constituents. Graphite also is seen in the thin sections in the form of little leaves. The rock has the pavement structure commonly found in rocks of this class, but the quartz shows distinct evidence of strain.

Another fine series of exposures of this rock is that on concession I of the township of Harburn, on the road between lots 5 and 6. Here there are large exposures of serpentinous crystalline limestone interstratified with beds of typical rusty gneiss carrying graphite. The rock is dark grey on a fresh fracture. Under the microscope the rock is seen to be composed of microcline, with a subordinate amount of plagioclase, and some quartz. It also contains much pyrite and graphite, the former in small masses of irregular shape, the latter in the form of little leaves. The pyrite runs in between and encloses individuals of the other constituent minerals of the rock, while the graphite lies between the grains of the other constituents. The graphite was apparently developed during the recrystallization of the rock.

while the pyrite may have been developed at this time, or introduced later. This rock also displays the pavement structure, and no evidence of cataclastic structure can be detected.

Still another large development of these sedimentary gneisses is included in the band made up of these and other closely related rocks which extends from Minden into Stanhope. From Stanhope the band runs in an easterly direction through the southern part of Guilford, the southwest corner of Harburn, and thence into Dudley, covering a small area in the northern part of this township in the vicinity of Wicksteed post-office. A hand specimen collected on concession V of Stanhope shows a pale grey fine-grained schistose rock, which weathers from a pale yellowish brown to a deep brown colour.

The thin section shows an interlocking aggregate mainly of quartz, together with a considerable proportion of feldspar, much of which is microcline. Some of the unstriated grains may be orthoclase. Plagioclase, with the extinction angles characteristic of oligoclase, is also present in very notable quantity. The most conspicuous and abundant of the dark colour constituents is graphite, which is intimately associated with, and frequently embedded in the biotite. The graphite is in irregular scales, plates, and imperfect crystals, arranged in such parallelism as to emphasize the foliation of the rock. The biotite is the usual pale brownish or bleached variety so characteristic of these gneisses. It also has a marked parallel disposition, and is often altered to chlorite. Muscovite is also present in intimate association with the biotite, and in larger individuals. Zircon (?) occurs in comparatively large, rounded and somewhat stout prisms. Apatite is only sparingly represented in minute more or less rounded prisms. Rutile occurs in very minute brown acicular crystals. Pyrite in small irregular grains is scattered through the rock, and much of it is undergoing decomposition to hydrous oxide of iron. Some of the quartz is in the form of small secondary veins intruded parallel to the schistosity, and is unusually free from strain. The constituent minerals are unusually fresh, the feldspar showing only a slight turbidity, due to decomposition. The rock shows only very slight evidence of pressure in the strain shadows induced in the quartz grains.

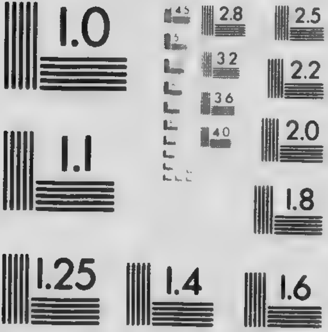
A fresh specimen of this rock was analysed by M. F. Connor, B.Sc., with the following results:—

SiO_2	79·70	per cent.
TiO_2	0·30	"
Al_2O_3	8·29	"
Fe_2O_3	0·41	"
FeO	0·17	"
MnO	0·03	"
CaO	0·67	"
BaO	0·08	"
MgO	0·76	"
Na_2O	1·43	"
K_2O	4·11	"
P_2O_5	0·04	"
Graphite	3·00	"
S	Undet	"
H_2O	0·70	"
	99·69	per cent.

From this analysis the mode or percentage mineral composition of the rock can be calculated, and is found to be as follows:—

Quartz	55·20	per cent
Orthoclase	18·94	"
Oligoclase	14·46	"
Biotite	3·45	"
Muscovite	3·50	"
Rutile	·30	"
Apatite	·09	"
Calcite	·28	"
Graphite	3·00	"
Water	·54	"
	99·76	per cent.

Although the amount of carbonic acid present was not determined in the analysis of the rock, the percentage of calcite present has been arrived at by calculating as carbonate, the lime remaining over after calculating the amount of biotite present and the percentage of the anorthite molecules required for the plagioclase.


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5

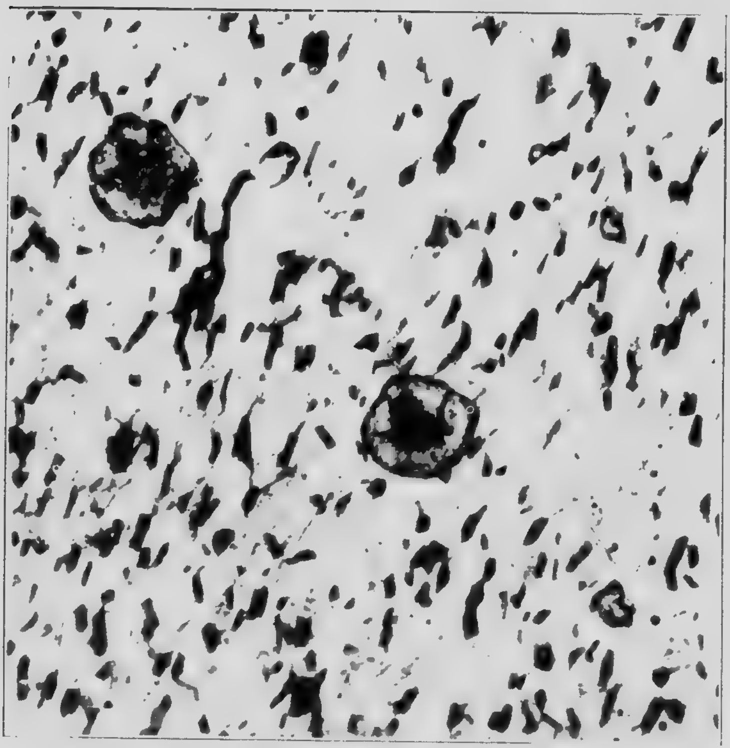
If the norm of the rock be calculated and its position in the quantitative classification be determined, this will be found to be as follows:—

Class 1.—Persalane.
Order 3.—Columbare.
Rang 2.—Alsbackase.
Sub-rang 3.—Tehamose.

This Tehamose is a division which includes many granites and liparites, so that, so far as its chemical composition is concerned, the rock might be of igneous origin. There are, however, few granites or rhyolites which contain so high a percentage of silica. Its mode of occurrence and structure, moreover, indicate a sedimentary origin. It probably represents the product of re-crystallization of some arkose material derived from the disintegration of granite.

Probably the thickest body of the typical rusty weathering paragneiss which occurs in the area is that which is seen crossing the Central Ontario railway between Ormsby Junction (Summit) and Ormsby, in the township of Limerick. It occupies the eastern half of this stretch of railway, and has been included by Dr. Barlow, in his mapping of this portion of the Bancroft sheet, within the amphibolite band which here runs north from Bass lake. The band of gneiss has a width of approximately a mile. It is light grey to a very dark grey on a fresh fracture, but weathers with an intensely rusty surface. A typical specimen of the rock, taken from a cutting on the railway track half a mile west of Ormsby Junction, when examined under the microscope, was found to be very fine and uniform in grain and to possess a distinct foliation. (See Plate XLI). It shows a colourless allotriomorphic base, consisting chiefly of quartz and feldspar, through which are distributed a great number of little flakes of biotite, separate from one another, but all with a marked parallel alignment. The biotite is strongly pleochroic in deep brown and pale yellow colours. The feldspar, which is clear and colourless, shows no twinning. Some of the quartz grains are nearly round and have an appearance strongly suggestive of sand grains. In addition to these minerals there is present as an accessory constituent a small amount of garnet, in individuals having a well marked polygonal outline, showing that the mineral has a good crystalline form. It is quite isotropic in character. There are also a few little rounded grains of zircon or

Plate XII



Microphotograph of paragneiss (rusty gneiss). Half a mile west of Ormsby Junction, Central Ontario railway. Ordinary light
Magnified 75 diameters

sphene, as well as a small amount of hydrated oxide of iron, occurring as minute grains, whose form suggests their derivation either from a rhombic pyroxene such as occasionally occurs in rocks of this class, or possibly from pyrite. No pyrite, however, occurs in the sections, neither are there any carbonates present.

Other specimens were collected from a cutting on the railway one hundred yards west of Ormsby Junction. These were similar in character to the rock just described. A microscopic examination, however, showed that while less biotite was present, the rock here contained a large amount of a yellow sulphide of iron, apparently pyrrhotite. Quartz and orthoclase are the most abundant constituents in this rock, which also contains a few grains of muscovite and zircon, the former mineral occurring in occasional large individual skeleton crystals. The grains of the yellow sulphide have an irregular outline, or are present in the form of little strings running parallel to the foliation of the rock. When examined by reflected light, nearly every grain of this sulphide is seen to have intimately associated with it a black mineral with a metallic lustre, which is evidently magnetite. This latter mineral usually forms a border around the yellow sulphide, which wholly or partially encloses it. These metallic minerals occur not only in larger grains, but also as a fine dust scattered throughout the rock.

At one place by the side of the road bed a band of this gneiss has been opened up by a small pit, it evidently being considered as an iron ore. This variety of the rock is black in colour on a fresh fracture, and when examined under the microscope is seen to be composed chiefly of quartz, hornblende, and magnetite. The hornblende is arranged in rudely parallel lines, giving the rock a distinct foliation. It is deep green in colour, and distinctly pleochroic in greenish and yellow tints. The magnetite has a black metallic lustre, and frequently possesses a good crystalline form. An immense number of very minute garnet crystals occur through the rock, resembling those in the rusty gneiss above described, but very much more abundant. Although so small, they [illegible] rather uniformly distributed, occurring not only in the horn[illegible]de and quartz, but also in the magnetite. They are isotropic likewise and possess a good crystalline form.

This band of gneiss suggests in its appearance in the field certain belts of the magnetite grünerite schist in the Iron ranges

on the south side of Lake Superior. The microscopic examination of the rocks, however, shows them to be quite different from the schist in question—biotite being the only iron-magnesia constituent present, except in the case of the narrow band above referred to as having been mistaken for an iron ore, and which contains hornblende. Carbonates are also absent, except in traces, and the iron is thus present almost exclusively in the form of a disseminated sulphide, the rocks belonging to the ordinary rusty weathering paragneisses so extensively distributed throughout the sedimentary portion of the area.

A variety of this paragneiss, presenting a striking appearance, occurs interstratified with limestone half a mile south of Ormsby, on the Hastings road, and is also seen on the road about half a mile east of the same place. It is a fine-grained, well-foliated gneiss, very rich in biotite, but holding, very thickly distributed through it, large white crystals of scapolite, often an inch in length.

A very similar rock is exposed on lot 14, concession III of the township of Lake.

Quartzite is not common. The best and most extensive development of this rock is that which forms a band running in a southwesterly direction from a lake situated on lots 26 to 29 of the last concession of Monmouth, as far as concession X, a distance of eight miles. This is interstratified with crystalline limestones and bands of rusty paragneiss. It is well exposed about the shore of the lake above mentioned, and is also well seen at the dam on Otter creek, on lot 25, concession XIV of Monmouth. Quartzite is also present on the shores of Otter lake, on concession XVI of Monmouth.

The quartzite is not composed exclusively of quartz, although that occurring on lot 23 of concession XVI of Monmouth, along the shores of Otter lake, contains comparatively little impurity, and is rather coarse in grain. The quartzite occurring on the lake shore, on lot 28, concession XVII of Monmouth, contains about 70 per cent of quartz. It is well foliated, rather fine in grain, and, under the microscope, is seen to contain, in addition to the quartz, a very considerable amount of a pale green pyroxene. This rock has a well defined parallelism, the quartz being in the form of elongated grains of irregular shape, marking the direction of the foliation. These between crossed nicols

show intense strain shadows. The twisted grains along lines of most intense strain develop minute fissures. The pyroxene has the form of irregular allotriomorphic individuals, rudely arranged in parallel alignment. As accessory minerals, a little microcline, sphene, and calcite are present.

The quartzite belt, where exposed in the vicinity of the Otter Lake dam, is finer in grain, and contains a considerable amount of accessory feldspar in some bands.

Quartzites also occur in thin bands, alternating with crystalline limestones and micaceous paragneisses, on lot 28 of concession XI of Monmouth.

All these quartzites show distinct banding, and have the appearance of being very highly altered and recrystallized siliceous sediments.

THE LIMESTONES AND DOLOMITES.

In the area of ancient crystalline rocks which underlie that portion of the Northern Protaxis described in the present report, limestones, as has already been shown, occupy a very prominent place. They, of course, are found only in the southern half of the area, as there alone the overlying mantle of sedimentary rocks survives. In the great area of igneous gneisses forming the northern half of the area the limestones are only found here and there as isolated inclusions, often of large size, occurring chiefly along the border of the sedimentary series. In the northwestern corner of the district, which is that most remote from the sedimentary cover, no limestone whatever has been found.

Throughout the area embraced in this report the limestones are found for the most part in a very highly altered condition, being coarsely crystalline, white in colour, and usually more or less impure, owing to the presence of grains or scales of certain silicates. These silicates occur not only disseminated through the rock, but are often especially abundant along certain lines or bands, thus giving to the limestone a foliated or stratiform appearance. This is the usual character of the Laurentian limestones in all parts of the Dominion. As developed in central Ontario they cannot be distinguished from the limestones of the Grenville series in Logan's original area in the county of Argenteuil, in the Province of Quebec. The area of the Haliburton and Bancroft sheets, however, is one which offers much greater opportunities for a satisfactory study of these limestones than that presented by Logan's original or type locality. This arises from the fact that in the southeast portion of the Bancroft area the same limestones are found in an almost unaltered condition, and all stages of the passage from the least altered to the most altered can be traced in many different places. At several points, moreover, enclosed in the very heavy bands of coarsely crystalline white limestone which occur in the southwestern portion of the area, surviving remnants of the original limestone were found, fine in grain and blue in colour.

On account of peculiarities in mode of occurrence which these Laurentian limestones present in certain localities, and which are connected with the extreme alteration which they have undergone, and the intense movements to which they have been subjected, some writers on the Archaean have been led to consider them as having been deposited directly from solution, and as allied genetically to the gangue matter in mineral veins.

The investigations in this area, however, entirely disprove such views, and show conclusively that the coarsely crystalline Laurentian limestones or marbles were originally fine-grained limestones of a bluish or drab colour, similar to those seen in the more recent sedimentary deposits, but which, by the forces of metamorphism, have been so completely altered that, except in some few places, all traces of their original character have been completely obliterated. The highly crystalline limestones of Logan's original Grenville area undoubtedly originated in this way, but to the south, where their unaltered equivalents would naturally be sought, the Palaeozoic strata come in and conceal the underlying Archaean.

Although these rocks have been and are commonly referred to as limestones, they are in some places magnesian, and in others are represented by true dolomites. This is the case in both the altered and the unaltered varieties. True limestones, however, are much more abundant than the magnesian varieties.

Specimens of certain of these dolomitic varieties from several different parts of the area, which, from their deportment with acid in the field seemed to have an exceptionally high content of magnesia [illegible]n analysed in the chemical laboratories of McGill [illegible] order to ascertain whether there might not be amon[illegible]e true magnesites. In every case, however, it was fo[illegible] lime was present in large amount, and that the rock was a dolomite.

The limestones and dolomites resemble one another so closely, both in the comparatively unaltered and in the coarsely crystalline varieties, that it is impossible to distinguish them by the eye. In the case of the latter, however, the dolomite is harder and less friable in character; it is also noticeably heavier, and in some cases has a more or less marked tendency to rusty weathering. This, however, is by no means invariably the case. In the unaltered varieties the dolomites can be distinguished from the limestones only by means of a direct chemical test.

WHITE CRYSTALLINE LIMESTONES.

As has been mentioned, the coarsely crystalline varieties of these rocks are by far the most abundant. In these the calcite individuals usually have a diameter of from 2 to 7 millimetres. From this, which may be taken as indicating the usual coarseness of grain, the limestones become finer and finer in grain as they are found in progressively less altered forms; while, on the other hand, the grain increases greatly in size when the forces of metamorphism have acted with especial intensity, as, for instance, along the immediate contact of the limestone bodies with granitic intrusions. As a locality where the limestones are found in this very coarsely crystalline condition, the cliff on the south side of Burnt river, just east of Maxwells crossing, in the township of Glamorgan, may be cited. Here the Glamorgan batholith comes against the limestone which underlies the southern portion of the township, and renders it very coarsely crystalline, the calcite individuals often measuring over 25 millimetres, or 1 inch in diameter. A similar occurrence is found on the east side of the batholith in the southwestern portion of the township of Cardiff. Here on lot 7, concession VI, the calcite individuals composing the limestone measure 30 to 40 millimetres, or even more in diameter; while at still another place on the same lot there is a body of limestone of which the constituent calcite grains measure 75 millimetres, or 3 inches in diameter.

In colour, these coarsely crystalline limestones, when free from silicates, are usually white. In some localities, however, they have a pinkish, and in others a salmon colour. Large bodies of limestone having the former colour occur along the shores of Salmon lake, in the township of Limerick; while about the Horseshoe bridge on lot 10, concession VIII of the township of Minden, there are great bodies of limestone of the latter tint, forming a very handsome rock. These colours are not due to the presence of any foreign mineral but belong to the calcite itself. They are much less intense on the weathered surface than on a fresh fracture, and disappear when the rock is heated to redness.

The limestones in some parts of the area are almost free from the silicates and other minerals which are usually present in them, and form great bodies of pure marble. This is usually too coarse in grain to permit of its being used for the purposes for which the

best qualities of marble are employed, a fine saccharoidal texture being seldom seen, but nevertheless in many localities marbles of good quality could be obtained, which would make beautiful building stone and would serve the purposes for which marble is ordinarily employed. Some years since a small quarry was opened up on lot 2, concession VI of the township of Glamorgan, near the line of the Irondale, Bancroft and Ottawa railway, and some marble taken out which was used for tombstones, several of which may now be seen in the cemetery at Gelert. The stone has a good appearance, being pure white in colour but rather coarse in grain. In some blocks a few small grains of iron pyrites are seen.

A great development of nearly pure marble is found in the same township, to the south of Contau lake, where it is excellently exposed along the Kinmount road.

There is also a fine body of this marble exposed on the shores of the western half of Deer lake, on concessions XIII and XIV of the township of Cavendish. The exposures are very extensive, especially about the northern end of the lake, where the rock has a well-bedded appearance, striking N 10° 15° E, the beds being nearly vertical.

Great bodies of marble, which is usually fairly pure and which in many places contains very little foreign material, are found forming the shores of Jack lake in northern Methuen, and extending across into the adjacent township of Burleigh, in the southeastern portion of which the occurrences are very large. Another large body is found on lot 12, concession I of the township of Anson.

Affording a marked contrast to the rock from the localities above mentioned, is an occurrence of limestone on the northwestern part of lot 29, concession XI of the township of Cardiff. Here the rock is developed in places as a beautiful cream-coloured alabaster, which is so fine in grain that its crystalline character can only be recognized under the microscope. This rock was supposed by the residents in the vicinity to be gypsum, but is in reality a very fine-grained limestone. It contains in places large twisted individuals of calcite as if the structure were due to cataclastic action. This peculiar structure will be referred to later.

Many other bodies of what may be correctly described as marble are found elsewhere in the bands of crystalline limestone.

the distribution of which is shown in the maps accompanying this report. Those referred to above are, however, worthy of special mention.

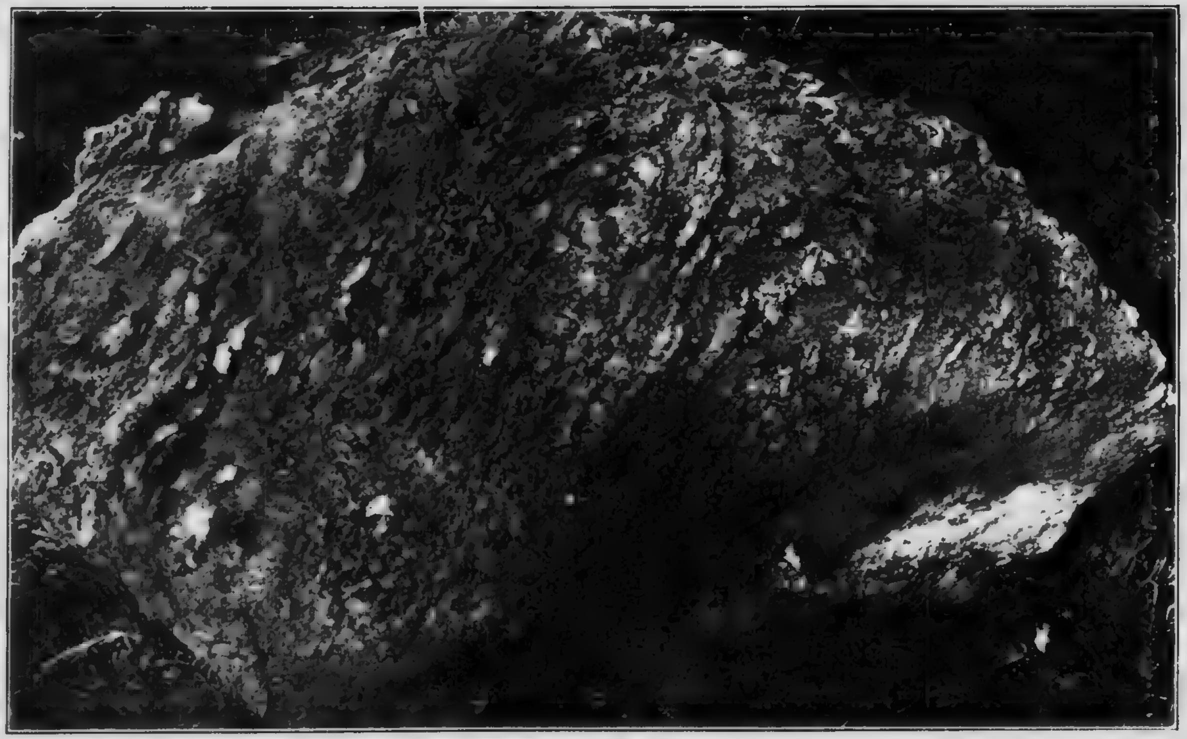
The crystalline limestones are, however, as a general rule more or less impure, owing to the presence of various minerals, chiefly silica and silicates. The distribution of these minerals is in some places comparatively uniform throughout large masses of the rock; while in other instances they have been developed in approximately parallel position corresponding with the original planes of sedimentation, thus emphasizing this structure. Moreover, mica, graphite, and other minerals, which occur in the form of leaves or scales, usually lie with their longer axes in the plane of the bedding, thus tending to give to the rock where they are abundant, a distinct foliation. These harder and more impure bands usually weather out in relief, limestone occupying the pitted or indented intervening spaces. (See Plates XLII and XLIII.) A typical foliated micaceous variety of the limestone occurs on lot 32, concession XVII of the township of Anstruther. Speaking generally, it may be said that the most impure limestones are those which lie near the contact of the granite batholiths or other large bodies of similar intrusive rock, and the description and discussion of these very highly altered varieties is accordingly given in the chapter treating of the "Granites and Granite-gneisses, their Inclusions and Contact Phenomena."

Some of the limestones which have been subjected only to a more moderate alteration or metamorphism are seen to contain certain impure, and for the most part, continuous bands. These are made up of the prevailing fine-grained, light greyish, rusty weathering gneisses representing originally interbedded clayey or sandy material. As compared with the beds of enclosing limestone these bands are much more brittle, and when subjected to any long continued or pronounced dynamic action are often torn apart, the more plastic limestone flowing apparently around and among the separated portions of the band, and accommodating itself to every change in position which it may assume. In exposures which have undergone the simpler stretching process the separated fragments are often quite angular and are readily traceable as one continuous band, but where extreme modification has taken place the fragments

PLATE XLII

Actinolite bands in dolomitic limestone, lot 55, Hastings road, Faraday township

PLATE XLIII.



Secondary or vein quartz in limestone, lot 32, concession A, Mayo township

have become so rounded and displaced, owing to differential movement and pressure, that the resulting rockmass presents in great perfection the character of an ordinary conglomerate containing fragments with every appearance of having been rounded by moving water. (See Plates XLIV and XLV.)

The most striking feature in connexion with these impure limestones, when they are examined under the microscope, is the peculiar rounded forms which the foreign minerals in them assume. The mineral in question, whether it be plagioclase, pyroxene, or biotite, first appears as a minute individual, often perfectly round, in the midst of a group of calcite grains, or sometimes completely enclosed in a single grain of the calcite. The grain then grows, always retaining a rounded form and very sharply defined outline, cutting across the adjacent calcite grains without apparently being in any way influenced by them. Sometimes inclusions of calcite, also rounded in form, will be seen in the grains in question. At other times a group of grains of silicates of the same, or of different species, will be formed by individuals which started to grow near one another coming together. In these cases allotriomorphic rounded aggregates of silicate grains result, and it becomes evident that if this growth of silicates through the limestone continued, a typical allotriomorphic pyroxene gneiss, pyroxenite, or amphibolite of some kind would result, dependent on the relative proportions of the different mineral species present.

In Dr. Sterry Hunt's valuable paper on the Laurentian limestones of North America[1] a list of 48 mineral species is given, which had been discovered in these rocks at the time when the paper in question appeared. While an exhaustive study of the mineralogy of crystalline limestones in the area covered by this report would probably lead to the recognition of most of the species enumerated by Dr. Hunt, considerably over one-half the number of these species has already been discovered in the limestones of this area, and in addition to those, a number of species not mentioned in Dr. Hunt's paper have been observed.

It may be mentioned in this connexion, that Dr. Hunt has included in his list minerals which occur not only in the limestones, but in the accompanying beds of pyroxenite, gneiss, etc., and that his list also includes a series of peculiar zinc ores which occur only in a small area of crystalline limestone in New Jersey, supposed to be of Laurentian age.

---

[1] Geological Survey of Canada, Report of Progress, 1863-66, p. 199.

The following is the complete list of species, 37 in number, which have been found in the Laurentian limestones of the area at present under discussion, arranged in alphabetical order:

Allanite	Orpiment
Apatite	Orthoclase
Barite	Phlogopite
Biotite	Plagioclase
Calcite	Pyrite
Chondrodite	Pyroxene
Dolomite	Pyrrhotite
Epidote	Quartz
Galena	Realgar
Garnet	Scapolite
Graphite	Scorodite
Hornblende	Serpentine
Loganite	Sphene
Magnetite	Spinel
Microcline	Tourmaline
Mispickel	Wilsonite
Molybdenite	Zinc blende
Muscovite	Zircon
	Zoisite

Mr. Dillon Mills, in a paper[1] on the molybdenite deposits in the altered limestone (pyroxenite) of lot 3, concession I of the township of Harcourt, mentions the occurrence in that deposit, in addition to certain of the minerals in the lists given above, of the minerals arsenic, bornite, marcasite, spodumene, and sulphur. These, if added to the list, bring the total number of species observed up to 42, or four less than the number recorded in Dr. Hunt's list for the limestones of the whole of North America.

Allanite. This mineral occurs with black garnet, scapolite, and other silicates in the Paxton iron ore, which is associated with the crystalline limestone on lot 5, concessions V and VI of the township of Lutterworth.

Apatite. This mineral is widely distributed through the limestones in the form of minute prisms or rounded grains of a pale green colour. It is, however, more abundant in the masses of granular green pyroxene (coccolite) which are so often found

[1] Report of the Ontario Bureau of Mines for 1902, p. 47.

PLATE XLIV.

Amphibolite inclusions in crystalline limestone, lot 69, Hastings road, Wollaston township

PLATE XLV.

Pseudo-conglomerate (autoclastic rock), lot 12, concession III, Wollaston township.

in the form of irregular veins or streaks in the limestone, especially near the contact with intrusions of granite. It is rarely that apatite cannot be found, in small quantities at least, in occurrences of this rock. This same granular pyroxenite is almost invariably found in connexion with the large deposits of apatite which in former years were so extensively worked in the Laurentian of Ottawa county, Que., and was there regarded by prospectors as the best indication of the presence of apatite. This rock has been described in the section of this report dealing with the metamorphic products of the granite intrusions. As a locality where apatite occurs in this manner, lot 28, concession I of Dysart (see p. 384, Economic Resources) may be instanced. Also several points on the north shores of Baptiste lake, on lots 27, 28, and 29, concession VI of Herschel. Crystals of apatite of considerable dimensions are found in the limestones on lot 39, concession XVII of Anstruther, near the shore of Eels lake, and are remarkable for the development of the basal plane, which is unusual in the occurrences of this mineral in the Laurentian limestones. Three occurrences of this mineral with calcite have been referred to under the heading of calcite, in the present list. Apatite crystals have also been obtained on lot 22, concession XIX of Cardiff, and on the north end of lot 8, concession XII of the same township, where they are stated to occur in veins of calcite.

Barite.—This mineral, in some cases white and in other cases red in colour, occurs associated with galena and calcite in a number of veins cutting the limestone in the townships of Tudor and Lake. The veins are in some cases as much as 2 feet in width, and several of them have been opened up and worked for the galena with which the barite is associated. Reference is made to them in the section dealing with economic geology. (See p. 347).

Biotite.—Referred to under phlogopite.

Calcite.—Of the calcite constituting the great stratified masses of the limestone in this district, it is unnecessary here to speak, as the structure and microscopical characters presented by the mineral will be discussed below. In the Laurentian in other parts of North America, calcite veins are often found traversing the strata of the limestone group. These veins in some cases consisted of nearly pure calcite, generally coarse in grain, but in other cases contained crystals of apatite, phlogopite, pyroxene, and other minerals. It was these veins cutting across the

apparently bedded strata of the Laurentian which contributed largely to the opinion, wide-spread among the early students of American geology, that the crystalline limestones of the Laurentian were of eruptive origin. In this district, curiously enough, while there is an enormous development of the bedded limestones, very few of these calcite veins have been found. Three occurrences may be mentioned. The first consists of a number of veins which are found cutting the fine-grained gneiss that is associated with the limestone on lo 3, concession X of the township of Monmouth. The veins in question are weathered away at the surface, giving rise to a series of crevices, in some cases as much as a yard in width, at the bottom of which, in digging away the soil which has partly filled them, the vein is laid bare. They consist chiefly of coarsely crystalline pink calcite, through which are distributed large crystalline masses of hornblende, and large crystals of apatite. It was the presence of the latter mineral in the veins which directed attention to the occurrence at first, leading to the hope that the veins might yield a sufficient amount of apatite to be worked for this mineral.

Another occurrence is that supposed to be an iron mine, on lot 27, concession XV of Glamorgan. Here, cutting a rock which microscopically resembles a mica syenite, are several well-developed veins, one of which can be traced on its strike for over 60 yards, reaching in places a width of 4 feet. The vein matter is coarsely crystalline, and consists of pale pink calcite, with apatite, sphene, biotite, hornblende, orthoclase, and magnetite. The last mentioned mineral makes up about one-half the vein. It is strongly attracted by the magnet and is in places a natural magnet. It often shows good octahedral form, more especially when it forms a band on the side of the vein. In these cases it grew into the calcite, or the calcite was deposited around it after its crystallization had been completed. Groups of perfectly formed sphene crystals, black in colour, were found partially embedded in the magnetite, and apatite crystals occur in both the magnetite and the calcite. Other veins, up to 4 feet in width, on this same lot, contain relatively more mica and have been opened up for the purpose of obtaining this mineral. The mica is, however, very dark in colour, being black in the hand specimen and very deep brown by transmitted light. Crystals of this mineral as much as 6 inches in diameter were seen.

It seems probable, from what is known of occurrences in other parts of the Laurentian in Canada where those veins are more abundant, that a gradual passage could be found from veins consisting chiefly of calcite to those consisting essentially of quartz and orthoclase, and which belong to the class of the pegmatites. The group of veins just referred to, holding as they do both calcite and orthoclase, belong to this transitional type, although, occurring in a rather dark basic rock, they are much richer in iron bearing minerals than usual.

A third occurrence, however, approaches much more nearly to the class of the pegmatites. This is a vein occurring on lot 15, concession XI of the township of Monmouth. This deposit was at one time worked for apatite, and a considerable quantity of this mineral was taken out. The pegmatite dike or vein, here, cuts a banded quartzite, and is for the most part rather fine in grain, although it varies greatly in size of grain from place to place. Associated with the orthoclase in the coarser grained parts of the vein are great masses of dark green hornblende in the form of irregular patches or streaks, the individuals of hornblende being in some cases as much as a foot in diameter. Together with this hornblende are found masses of red and green granular apatite, coarsely crystalline calcite, black mica, dark green pyroxene, sphene, and a little pyrite. The masses of apatite are in places as much as a yard across. The calcite, however, in this occurrence forms a comparatively small part of the whole.

Chondrodite.—This mineral was found in only a single locality, namely, on the line of the Irondale, Bancroft and Ottawa railway, where it crosses the front of lot 11, concession i of the township of Harcourt. It occurs rather abundantly in the form of bright orange grains, associated with a pale green phlogopite, and a little pyrrhotite and spinel, in certain beds of the limestone found at that locality. When examined under the microscope the smaller grains of chondrodite are seen to be round or egg-shaped in outline, and to lie embedded in the calcite individuals. The larger grains are more irregular in shape, but always possess rounded outlines. They are pleochroic, brownish-yellow, and colourless, have a high double refraction, and are often twinned.

Dolomite.—As mentioned above, the crystalline limestones of the area are in many places magnesian, as can be easily ascertained by observing the comparatively slight effervescence produced by

the application of acid to the fractured surface of the rock. In other places the amount of magnesia is still larger, and the limestone passes into a true dolomite. Whether this dolomite is an original magnesian sediment or whether it results from the alteration of the limestone cannot in all cases be determined. It is, however, in certain parts of the area connected with the presence of intrusive rocks which cut the limestone, the intrusions in question altering the limestones to dolomites. This is notably the case in the district about the southern half of Paudash lake, in the township of Cardiff. Here the limestone becomes converted into a dolomite along either side of the long tongue of dioritic amphibolite which crosses the southwestern bay of the lake in a northeast and southwest direction, and which is an intrusion, more or less altered by subsequent metamorphic agencies. The limestone band also takes on the character of dolomite along its contact with the amphibolite, which forms a portion of the shore on the southeastern bay of the lake. Here the mode of occurrence indicates that there has been a dolomitization of the limestone through the action of the basic igneous intrusions. Dolomite is frequently seen under similar conditions elsewhere, and especially in the eastern half of the area, where gabbro or gabbro-diorite intrusions are numerous; and basic amphibolites, which are probably in many cases of volcanic origin, are widely distributed.

As has been shown, the limestones at the contact of the granite batholiths are, in many cases at least, converted into amphibolites, which implies an addition of magnesia, among other substances, to the original limestone. It might thus be expected that about the granite intrusions a process of dolomitization might also be observed. Along these granite contacts, however, the limestone usually appears to be altered directly into silicates, without the intervention of a dolomitic stage. About the contact of the granite intrusions with the limestones on the western side of the township of Glamorgan, on concessions IV and V, however, coarsely crystalline white dolomite is abundant. It forms large exposures on the south shore of Contau lake, and occurs also on the east side of Devil lake, and at the contact just east of Maxwells crossing. In these cases, it is not quite certain that the dolomite owes its existence to the presence of the granite, since the distribution of the dolomite does not bear a constant relation to the borders of the granite masses, crystalline limestone of the or-

dinary type often intervening between the granite and the dolomite occurrences in question.

Epidote.—This mineral is found in some places in the highly altered limestone. Thus it occurs in association with the reddish brown pyroxenite which results from the alteration of the limestone on the shores of Farragut lake in the township of Harcourt. It is also found, in company with pyroxene, scapolite, and sphene, in the altered limestone on lot 15, concession VI of the township of Glamorgan. At the latter locality it occurs in the form of rather large grains, with the usual prismatic habit, growing into the individuals of scapolite, sometimes in sponge-like forms, and at other times with good crystalline terminations. It is also found in large individuals in the curious gneiss, evidently an altered limestone, which occurs on Pine lake, on concession III of the township of Monmouth, and which is described on page 112.

Galena.—This mineral was observed, in association with graphite, disseminated throughout the crystalline limestones on lot 13, concession XIV of the township of Lutterworth. It also occurs in association with zinc blende in the limestone of lot 13, concession V of the township of Cardiff. Veins holding galena in a gangue of calcite and barite occur at several places in the townships of Tudor and Lake. Several of these have been opened up and worked for lead. (See page 347).

Garnet.—The sedimentary gneiss (paragneiss) occurring associated with the limestones is often rich in garnet, but the mineral rarely occurs in any considerable amount in the limestone itself. In connexion with the bed of iron ore on lot 20, concession I of the township of Snowdon, which occurs in crystalline limestone, small bands of red garnet rock are found, and the mineral also occur elsewhere on the same lot, as thin bands in the limestone, associated with granular green pyroxenite.

Graphite.—The organic pigment which colours the blue and apparently unaltered limestones of the area, when these are altered to white crystalline limestones becomes for the most part oxidized and destroyed, but a portion of the carbon in some cases survives in the form of disseminated scales of graphite. Small quantities of graphite, therefore, occur in the crystalline limestones of many places in the area, more especially in its western half. As localities where such occurrences are to be found, lot 20, concession

III of the township of Dudley, and lot 10, concession XIV of the township of Monmouth may be mentioned. In other places the graphite is found in larger quantities in the limestones, in the form of veins or large masses. Two of these occurrences, which have been opened up in order to ascertain whether the graphite was present in workable amount, are described in the section treating of the economic geology of the area; the first of these localities being on lot 30, concession IV of Glamorgan, and the second on lot 32, concession XIII of Monmouth.

Hornblende.—The limestones along the borders of granite batholiths frequently contain hornblende. The mineral is only one of a number of mineral species developed under these circumstances, and is not present in large amount, being always exceeded in quantity by the pyroxene which accompanies it.

When the limestone actually passes over into amphibolite, the change of course consists in part in the development of large amounts of hornblende in the rock, but until this stage of advanced alteration is reached, the quantity of hornblende is small. This hornblende occurs in the limestone in the form of rounded grains or in elongated rounded forms, and is of a rather deep green colour and strongly pleochroic. As localities where it occurs, the limestone along the southern contact of the Glamorgan batholith between Gooderham and Maxwells crossing, and the limestones along the eastern margin of the same batholith, about lot 27, concessions IX and X of the same township may be cited; also on lot 15, concession III of Dudley, and the very highly altered limestone band crossing Pine lake, on concession III of the township of Monmouth. In the township of Galway, which lies immediately to the west of Cavendish, and of which only the extreme northeast corner is included in the Haliburton sheet, there is a great development of crystalline limestone, and on lot 15, concession XIII, the limestone is filled with fine-bladed prisms of hornblende, often over an inch in length and in some cases nearly half an inch wide. These are white in colour and have the perfect prismatic form of hornblende, although without crystallographic terminations. Under the microscope they are seen to contain numberless small and irregular shaped calcite inclusions.

The presence of hornblende in certain calcareous veins has already been referred to under the heading of calcite.

Loganite.—This mineral, which is also probably an altered pyroxene, occurs in the limestones of the township of Tudor, forming the filling of the supposed chambers in the Tudor eozoon.

Magnetite.—So far as is known at present, magnetite very seldom occurs in the form of grains disseminated in the Laurentian limestones of this area. It has been noted occurring in this way only in one instance, namely, in an impure limestone on lot 15, concession III of the township of Dudley.

In many places, however, bodies of magnetite, often of very considerable dimensions, occur as beds or lenses interstratified with the crystalline limestones. In these ore bodies the magnetite is very frequently associated with a large proportion of various ferruginous silicates, especially pyroxene, hornblende, and garnet; and there is usually a considerable amount of calcite disseminated through the mass. It seems entirely reasonable to believe that these bodies in many, if not all cases, represent the result of a complete replacement of the limestone through the agency of iron-bearing solutions or vapours. In the section of the report which deals with the alterations which the limestones have undergone, it is shown that the development of the silicates above mentioned in the limestones is frequently due to such metamorphic agencies connected with the proximity of igneous intrusions. In the case of the Coehill iron ore, there can be little doubt that the ore body has originated in this way, and, although the evidence is less striking, it is believed that the same is true of the Victoria, Paxton, and other similar iron deposits which occur in limestone near the margin of the great granite batholiths. A further discussion of this subject, and descriptions of the ore bodies referred to, will be found in the section dealing with the economic geology of the area.

Microcline. Referred to under orthoclase.

Mispickel. This mineral occurs associated with quartz on the lot owned by William Jeffrey, about seven miles west of L'Amable station of the Central Ontario railway, on concession IX of the township of Faraday. (See page 366). The vein probably occurs cutting limestone, as this is the country rock of this portion of the area. Associated with this mispickel, and chiefly in the form of a lining to fissures and cavities, small quantities of bright red realgar, sulphur-yellow orpiment, and deep green scorodite were found. (See page 367).

Mispickel also occurs on Bradshaw's lot, about the middle of the township of Dungannon, on concession VI. Here also it is associated with quartz and scorodite (?) and probably occurs as before as a vein cutting limestone and feather amphibolite.

Molybdenite.—This mineral is often found in the green pyroxenite which results from extreme alteration of the limestone. Occurrences of this nature are described in the section treating of the economic geology of the area. The mineral is also found seminated through an impure crystalline limestone along the shore of Eastmore lake, on lot 23, concession V of the township of Lutterworth.

Muscovite.—This species occurs in small scales in the crystalline limestone on lot 26, range B, of the township of Faraday, where it is associated with the fine blue scapolite of that locality, to which reference has already been made.

Orpiment.—Very thin coatings of a sulphur yellow mineral, which is apparently orpiment, are found associated with the mispickel mentioned as occurring on Jeffrey's lot on concession IX of the township of Faraday. From its mode of occurrence the mineral seems to be a decomposition product of the mispickel, and is everywhere so closely intermixed that it was impossible to make a sufficiently pure separation to determine its character with absolute certainty. There is, however, little doubt that the mineral is really orpiment.

Orthoclase (and Microcline).—Potash feldspar has been observed in a few places in the limestones around the border of the granite intrusions. It is abundant in a small body of limestone, about 30 feet thick, which is found enclosed in the granite gneiss on lot 19, concession I of the township of Sherbourne. The limestone here no longer forms part of any continuous band, but is an isolated limestone remnant enclosed in the granitic gneiss. It is exposed on the side of a high cliff by the side of Hawk lake and is penetrated by small strings of pegmatite. Little grains and lumps of orthoclase occur thickly scattered through the rock and seem to be quite distinct from the pegmatite strings. The rock also contains grains of quartz and other minerals, being extremely impure. Orthoclase, or rather microcline, occurs in large amount in the highly altered limestones found close to the granite on lot 10, on the line between concessions V and VI of the township of Dysart. This occurrence is described on page 120.

Phlogopite and Biotite.—The mica, which is one of the most frequent impurities in the crystalline limestones, is a magnesian species with more or less iron and varying in colour from pale yellowish brown to nearly black. It has a small axial angle and is in part phlogopite and in part probably biotite. It is usually more abundant in certain beds or bands in a limestone section, thus marking them off by their darker colour, and as a general rule the little leaves lie parallel to one another, giving to the rock when they are numerous, a sort of schistosity. Lot 32, concession XVII of Anstruther, and lot 11, concession I of Harcourt may be mentioned among the many localities where mica occurs in this way in the limestones. On lot 16, concession X of the township of Monmouth crystals of dark brown mica as much as 5½ inches in diameter are found associated with coarsely crystalline calcite, forming a streak or band in the finer grained limestone of this distric

As has been mentioned on page 93, at certain places near he granite contacts the limestone is almost entirely converted ito a rock composed of a rather fine-grained aggregation of biotite scales. This is one of the forms assumed by the limestone as the result of extreme alteration. A great development of the rock is found gradually passing over into the limestone on the road crossing lots 31, 32, and 33 of the rear line of the township of Faraday. Another occurrence is seen on the railway, west of Wilberforce.

Segregations or nests of biotite scales, sometimes composed of very large individuals of the mica, almost invariably occur in the granular green pyroxenite, which is another product of the extreme alteration of the limestone, and which has already been described. These pockets of mica have been opened up and more or less extensively worked for this mineral in several places, and are referred to in greater detail under the portion of this report dealing with the economic geology of the area.

Plagioclase. This feldspar is more common than the orthoclase, and is found not only in highly altered limestones, but in some cases in limestones which have undergone comparatively little alteration. As an example of the former the limestone near he granite contact on lot 10 of the line between concessions VI and VII of Glamorgan may be mentioned; while as an example of the latter the blue limestone occurring on lot 28, concession XI

of Monmouth may be cited. In this rock the plagioclase occurs in clear, fresh, well-twinned grains, all quite rounded in outline and with smooth even surfaces, the forms being identical with those seen in the case of pyroxene, and in fact of most other minerals in the limestones when the grains of the foreign mineral are small. Sometimes the little rounded grain consists of two or more plagioclase individuals, at times holding a rounded inclusion of sphene.

Pyrite and Pyrrhotite.—These minerals are very common in the sedimentary gneisses so frequently found in close association with the limestones, and which are so frequently characterized by a very rusty weathered surface owing to the oxidation of these sulphides. The limestones themselves hold these minerals less frequently, and in smaller amount. Pyrite occurs in the limestone of lot 15, concession III of Dudley, and pyrrhotite in that of lot 11, concession I of Harcourt.

In the townships of Galway and Somerville, which lie immediately to the south of the southwestern corner of the Haliburton sheet, pyrrhotite, associated with some pyrite, is, however, unusually abundant in both the gneisses and limestones, giving rise to ores resembling in appearance those from the Sudbury district and the north of Lake Huron. On this account a good deal of attention was attracted to this Galway district some years ago. An investigation, the results of which with numerous assays have appeared in the publications of the Geological Survey,[1] showed that while the Sudbury ores always occur in close association with igneous rocks of the gabbro family, and contain a pyrrhotite which is rich in nickel, these deposits of the Galway district always occur in association with crystalline limestones, or their accompanying rusty gneiss, and contain a pyrrhotite which does not contain more than traces of nickel. No more striking case is known of the influence of the adjacent rock on the character of ore deposits, and, as has been pointed out in the report referred to, these same associations bring about similar results in the case of pyrrhotite deposits in all other parts of the world where these are known.

As a locality in Galway where pyrrhotite occurs in the limestone, lot 11, concession XVIII may be cited, the mineral here

[1] Adams, Frank D. Preliminary Report on the Geology of a Portion of Central Ontario, etc. Ann. Rep. of the Geol. Survey of Canada, New Series, Vol. vi. 1892-93. Part J.

being found in grains or little strings, associated with graphite, serpentine, tourmaline, and other minerals.

Pyrite and pyrrhotite also occur as impurities in certain of the deposits of iron ore which occur associated with the limestones in various parts of the area. Reference to these will be made in the section dealing with economic geology

Pyroxene.—This mineral is one of the silicates most frequently found in these limestones. It occurs in hundreds of localities, and in every part of the area where the white crystalline limestones are found. As has been mentioned, the serpentine found in the limestones is probably in all cases an alteration product of pyroxene grains or bands. The mineral is, in the great majority of these occurrences, of a pale green colour and belongs to the class of the malacolites, diopsides, or sahlites. In other cases it is white in colour.

It is more especially abundant near the granite contacts, and as it increases in amount, in company with certain other silicates, the limestone passes over into various amphibolitic or gneissic rocks, as described on pages 101 et seq.

The development of the mineral in the limestones is very interesting as traced under the microscope, although the process is essentially the same as that which can be followed in the case of the other silicates which accompany it.

The pyroxene first appears as small perfectly round grains, without any suggestion of crystalline outline, embedded in the calcite. One of these little round pyroxene grains will often appear completely enclosed in a larger calcite individual. Sometimes the rounded grain is seen to be composed of two or more individuals. As it becomes larger the grain will exhibit a more irregular outline, the cleavages will become more distinct, and it can be more readily recognized as pyroxene. It is seldom that it attains good crystalline form. When much pyroxene is being developed in the rock, a great number of these rounded grains grow simultaneously, leaving the very irregularly shaped intervening spaces filled with the surviving calcite, and eventually in some cases entirely replacing the latter, giving rise to a granular green pyroxenite or coccolite. Or it may be that other minerals are growing at the same time and a rock of more complicated composition is produced. In the case of hornblende or mica the originally rounded forms more quickly develop a tendency toward prismatic

shapes, and in the highly altered limestones these are generally better crystallized than the pyroxenes. The same method of growth is seen in the pyroxene of the blue limestones of the township of Monmouth (to be mentioned later), when these are found in the stage of transition into the coarsely crystalline white limestones at present under consideration. The highly altered pyroxenic limestones, and the great masses of pyroxene rock formed by the alteration of the limestones in many parts of the area, are referred to in describing the changes produced by the granite batholiths in the rocks through which they rise.

The bodies of granular pyroxene rock in question often enclose small masses of very coarsely crystalline calcite, which seem to represent remnants of the original limestone rock, and into which large and very perfect crystals of the pyroxene grow from the surrounding pyroxenite. These larger crystals generally show in a marked manner the basal parting seen in sahlite and are referable to this variety.

The finest occurrence of pyroxene crystals which was discovered in the crystalline limestone of the area, is that on lot 3, concession IV, in the southeastern corner of the township of Herschel. Here there are large exposures of a very coarsely crystalline variety of the limestone, through which are thickly scattered immense numbers of fine pyroxene crystals of a greyish green colour, and often as much as three inches in diameter. The crystals are well terminated, showing the faces of the prism, both pinacoids, the unit pyramids as well as pyramids of at least two other values, and the basal planes. The basal parting is well marked. The mineral is associated in the limestone with hornblende, and a dark coloured mica in smaller amounts.

Fine masses of coarsely crystalline pyroxene are also found in the crystalline limestone in the hills just south of the village of Minden, in the southwest corner of the township of the same name. Here the mineral is usually somewhat altered, but shows the marked basal parting referred to above, and also can, in many instances be seen to have been bent and broken by the movements to which the limestones have been subjected.

Pyrrhotite.—Referred to under Pyrite.

Quartz.—This mineral occurs in the white marble from lot 10, concession VIII of the township of Minden, and also in the pink marble from the shore of Salmon lake, in the township of Lime-

rick. In both cases, however, the mineral is present in very small amount. It was also observed in small irregular-shaped masses in the crystalline limestones of the township of Burleigh, especially on lot 12, concession V. At this locality the calcite individuals of the marble show a very marked cataclastic structure, and the quartz grains show corresponding evidences of pressure when examined in polarized light, being twisted in the most striking manner, and frequently in process of being torn to pieces. (See Plate XLVI.) Rounded grains of quartz also occur in the blue limestone found on lot 28, concession XI of the township of Monmouth.

Realgar.—Very small quantities of bright red realgar occur associated with the orpiment and mispickel on Jeffrey's lot, in concession IX of the township of Faraday.

Scapolite.—This mineral is very common in the limestones, and is represented by a great number of varieties, differing from one another greatly in appearance. It is especially abundant near the granite contacts, and is almost invariably found in the amphibolitic rocks which result from the extreme alteration of the limestone. These have been already described. In these rocks, of course, the mineral occurs in small grains, its character, and in some cases even its presence in the rock can only be recognized under the microscope, but in other places in the limestone the scapolite occurs in large and often well-formed individuals, often presenting a fine appearance. One of these localities is in the township of Faraday, on lot 26 B. Here in the limestone, near its contact with the nepheline syenite, and associated with pyroxene, partially altered to serpentine, muscovite, and other minerals, a deep grey-blue scapolite occurs in abundance. Its colour at first sight suggests fluorspar. It has a specific gravity ranging from 2·58 to 2·624, and gives distinct reactions for both chlorine and sulphuric acid.

Another fine occurrence is found on lot 28, concession XIV of the township of Monmouth, near the contact of the nepheline syenite and the limestone, its exact relations not being clearly seen. It is found in large masses of a pale greenish yellow colour. The mineral occurs in the form of large irregularly shaped individuals, with a strong parting in one direction, and possessing the maximum hardness of scapolite, namely 6·5, and a very high lustre. It

gives a strong chlorine reaction, and has a higher specific gravity than the blue variety just mentioned, namely 2·65.

A beautiful colourless transparent scapolite, with a high lustre and low hardness, occurs in large crystals in the limestone at its contact with the granite, just east of Maxwells crossing on the south side of Burnt river, in the township of Glamorgan. Like the others it gives a chlorine reaction, and its specific gravity is about the same as that of the blue scapolite from Faraday, ranging from 2·57 to 2·62. A scapolite closely resembling this occurs associated with pyroxene and black mica near the granite contact on lot 7, concession V of Cardiff; while another white scapolite (which, however, is considerably altered but possesses a good crystalline form) is found in the limestone on lot 12, concession V of the township of Burleigh.

Fine crystals of a fresh scapolite, with high vitreous lustre, and of a pale greenish colour, are also found associated with calcite and other minerals at the Paxton iron mines, in the southeastern part of the township of Lutterworth, just beyond the limits of the Haliburton sheet. Many other occurrences might be mentioned.

Scorodite (?). A deep green mineral, which is in all probability referable to this species, occurs as a lining in crevices, and in minute cavities in the mispickel which is found on Jeffrey's lot on concession IX of the township of Faraday, and also in connexion with the deposit of the same mineral which has been mentioned as occurring on concession VI of the township of Dungannon. Unfortunately the mineral, while presenting all the physical characters of scorodite, occurs in such small amount, and so intimately mixed with the mispickel, that it is impossible to obtain it in a sufficiently pure condition to make quite certain of its composition, by chemical tests. There is, however, little doubt that the mineral is scorodite, and if so, it is the first time that the species has been found in Canada.

Serpentine. Serpentine is found, usually in small amount, in the limestones of many parts of the area. It is, however, by no means so abundant as many of the other minerals which these rocks contain. It occurs in the dolomite on lot 5, concession I of the township of Harburn, and on lot 10, concession III of Minden, but the most noteworthy development of serpentine limestone is in that district about Bob lake, in the townships of Anson and Lutterworth, which lie in the extreme southwest corner of the Haliburton sheet.

PLATE XLVI

Microphotograph of crystalline limestone, lot 12, concession V, Burleigh township, showing cataclastic structure and strain shadows. Between crossed nicols. Magnified 47 diameters.

On the shore of Big Bob lake, on lot 11, concession III of Anson, beds of highly serpentinous limestone are found, alternating with others consisting of pure limestone. On the little islands off shore on the same lot, additional exposures of the same rocks are seen. Much of this limestone is very rich in serpentine, the mineral having a dark green colour, and occurring in all sizes from little grains to masses nearly 2 feet in diameter. Another body of limestone very rich in serpentine occurs on the south of lot 11, concession II of Anson.

The crystalline limestone south of Bancroft contains serpentine in considerable amount, and much of it has a banded character suggestive of Eozoon.

A band of beautiful serpentine limestone also occurs on lot 13, concession XIV of Lutterworth, in the bed of a little stream which runs through the length of this lot. It is flanked on either side by a bed of the rusty weathering sedimentary gneiss so often associated with the Laurentian limestones, and at the point where the road traversing this lot crosses the stream, is exposed for a width of 30 yards. On going up stream from this point the limestone gradually pinches out, the bands of rusty gneiss flanking it on either side coming together. The serpentine, as before, occurs in grains, lumps, and masses, the largest masses being as much as 2 feet in diameter. While the small grains have a rounded outline, the large serpentine masses are sub-angular, as if they represented severed fragments of larger masses or portions of bands. Under the microscope the serpentine grains are often seen to be aggregated together into little groups, and to lie embedded in calcite individuals. They show the usual aggregate polarization in deep blue tints. A block of this limestone was obtained and sent to the Forsyth granite works in Montreal, where it was sawn and polished. The stone presented a very fine appearance after polishing, and was reported by the Company to be easily worked, and of excellent quality, and in their opinion of great beauty. Had it been on the market, the Company in question would have employed it in the interior decorations of the Canada Life Assurance building in Montreal, instead of certain foreign marbles which they were obliged to import.

The serpentine occurring in the Laurentian limestones of various parts of North America was considered by Dr. Sterry Hunt, and others, to be the result of direct aqueous precipitation. Micro-

scopic study, however, shows that there is no reason to believe that this serpentine is ever of other than metamorphic origin, thus resembling the serpentines of all other parts of the world. The appearance of the serpentine under the microscope, its rounded form, and the apparent absence of cleavage in the mineral from which it was derived, have led certain writers to the conclusion that it had resulted from the alteration of olivine. This, however, is not the case. Olivine has never been found in these limestones, nor is there any reason to believe that it ever exists, or ever did exist in them. Certain occurrences, however, show clearly what the original mineral was, by the alteration of which the serpentine was produced. When, for instance, some of the large serpentine masses occurring in the limestones on lot 11, concession III of Anson, are broken open, it is found that they enclose a nucleus of grey pyroxene rock. The same is true of some of the serpentine masses in the limestones of the adjacent lot, No. 12 of concession III. Here the pyroxene can be seen to pass into the serpentine, and it is quite certain that the latter is an alteration product of the former. There is every reason to believe that the small grains of serpentine disseminated through the limestone have originated in the same way; they have precisely the shape and outline of the grains of pyroxene which are found so abundantly in the limestones in other parts of the area. The absence of dominating lines through the serpentine, when examined under the microscope, is just what is to be expected, for the pyroxenes occurring in the limestones are varieties in which the cleavages are poorly developed, with the exception of the basal parting which is often strongly marked. This accounts for the resemblance which this serpentine bears to that produced by the alteration of olivine grains in basic igneous rocks. The sub-angular form of the larger serpentine masses, above referred to, is also explained by the fact that they represent in an altered condition the bands of pyroxenite so common in these limestones, and which are so frequently found pulled apart into fragments by the movements to which the limestones have been subjected. It has been shown in a former report[1] that the serpentine found in the Laurentian limestones in the Rawdon

[1] Adams, F. D. Report on the Geology of a Portion of the Laurentian Area lying to the north of the Island of Montreal. Ann. Rept. Geol. Survey of Canada. Vol. viii (1896). p. 65. Part J.

district of the Province of Quebec has originated from the alteration of pyroxene in precisely the manner above described, and Merrill[1] pointed out that is also the origin of the serpentine of Montville, New Jersey.

Sphene. This species is noted by Dr. Hunt as one of the commonest minerals in the calcareous veinstones of the Laurentian In the limestones in that portion of the Laurentian embraced in the present report the mineral is not, however, very abundant Good crystals of sphene may however be obtained from the crystalline limestone occurring immediately south of the corundum syenite in Raglan township. It occurs sparsely disseminated in a rather coarse-grained white crystalline limestone on lot 14, concession III of the township of Lake. It also occurs very frequently, although in small amounts, in the limestones, when these have been filled with various silicates by the processes of metamorphosis; and it is, as has been mentioned, almost invariably present in these amphibolites which have resulted from the extreme alteration of the limestones. Under these conditions it never occurs in well crystallized forms, but is always found as small irregular-shaped more or less rounded grains of a brown colour As localities where it has been observed in such impure limestones, lot 15, concession VI of Glamorgan, and lot 10 on the line between concessions V and VI of Dysart may be mentioned. Reference has been made on page 200 to the occurrence of sphene in groups of perfect crystals in a calcareous vein on lot 27, concession XV of the township of Glamorgan.

Spinel.—This species was found by Professor Miller in the limestones on the cliff by the side of the York branch of the Madawaska river, just above the first rapids below the village of Bancroft. The mineral occurs in groups of octahedra, with a brilliant lustre and a black colour, measuring in some cases nearly a quarter of an inch in diameter. Spinel also occurs, although in very small amount, in the pyroxenite from Farquart lake, mentioned above in connexion with epidote.

Tourmaline.—This mineral is not common in the limestones, but was found in small amount at two places in the township of Wollaston, namely, on lot 16, concession XII, and by the side of Eagle lake, on lot 14, concession VI. In both cases the mineral was very dark in colour.

[1] Proceedings of the U.S. National Museum 1888, p. 105.

W[illegible] [illegible] mineral, having a bright pink colour, occurs in the [illegible] of lot 13, concession XIV of the township of Lutterworth. It is here intimately associated with a colourless scapolite, of which it appears, as in many other localities, to be an alteration product.

Zinc Blende. This mineral occurs in small amount, associated with galena, on lot 13, concession V of the township of Cardiff. It is dark brown in colour.

Zircon. –A few rather large rounded grains of a mineral having the microscopic characters of this species were observed in the thin sections of an impure limestone, occurring on lot 15, concession III of the township of Dudley.

Zoisite. –Occurs in very small individuals in a comparatively unaltered blue limestone on lot 8, concession VIII of the township of Carlow, but has not been observed in the limestones of any other part of the area.

The crystalline limestones are usually granular in structure, that is, they are composed of calcite grains which are approximately equidimensional. Where the rock shows a foliation, this structure is due to the arrangement of small calcite grains in sheets between the larger calcite grains, or to the presence of foreign minerals similarly distributed, or which, like graphite and mica, lie with their longer axes in one plane. In some few cases, especially among the finer grained dolomites, the calcite or dolomite grains are seen under the microscope to be more or less distinctly flattened in one plane, thus producing an indistinct foliation in the rock. As rocks showing this structure, the dolomites on lot 15, concession IX of the township of Wollaston, and of lot 50, range A, of the township of Dungannon, may be instanced.

The calcite individuals usually have a border which shows minute crenulations, so that the adjacent grains to a certain extent interlock. These crenulations are much more pronounced in the limestones of some localities than in those of others. In the dolomites, especially when fine in grain, the individual grains show a tendency to a smoother and more even outline. This same difference in microscopic character has been noted by Vogt[1] in both the calcite and dolomite marbles, resulting from

[1] Der Marmor in bezug auf seine Geologie, Struktur und seine mechanischen Eigenschaften. Zeit. fur prak. Geol., Jan., 1898. p. 13.

regional metamorphism in Scandinavia and elsewhere, and has been figured by him. The perfectly smooth outlined calcite individuals which he has described as forming certain calcite marbles, which have originated from contact metamorphism, have not been met with in this area.

Two marbles from the Bancroft district, which contained some magnesia, but not sufficient to constitute true dolomites, were examined under the microscope in order to determine whether the magnesia was present in the form of grains of dolomite intermixed with the calcite grains, or whether it occurred as a molecular replacement of the lime in the calcite molecule. Sections of these rocks were in each case prepared, and were, following Lemberg's method, treated with a solution of ferric chloride for one minute. This was then washed off and the slide was treated with ammonium sulphide. This treatment by ferric chloride, in the case of calcite gives rise to the deposition of a thin pellicle of ferric hydrate, which by the ammonium sulphide is stained intensely black. In the case of dolomite no reaction is produced.

The first of the two marbles above mentioned occurs below the dam at the village of Bancroft, on the Hastings road. It was found to consist chiefly of grains of calcite, which when treated as above were stained black, but between these were found a few grains of dolomite of irregular form which remained quite unaffected by the test. In this case the rock clearly consisted of an admixture of calcite and dolomite grains.

The other marble was one showing an extraordinary coarseness of grain, from lot 7, concession VI of the township of Cardiff, on the east side of the Eels Lake batholith. The rock consists of individuals, which are in some cases as much as three inches in diameter, and when examined chemically is found to contain a considerable amount of magnesia; although not enough to constitute it a true dolomite.

On a broken surface of the rock the evenness of the cleavage faces of the calcite individuals is interrupted by little areas which lack the lustre and the smoothness of the true cleavage face. These under the microscope are found to be portions of other calcite individuals differently orientated. In fact, what at first sight appear to be large calcite individuals are in reality intergrowths of two or more individuals which present a very complicated interpretation. A similar occurrence from Segelfor

is figured by Vogt.[1] When sections of this Cardiff marble were tested in the manner above described it was found that no difference could be observed between the various individuals of the complex crystal. The reaction was not so strong as in a pure calcite, but it was everywhere equal in intensity, showing that in this limestone the magnesia occurs chemically replacing a portion of the lime in the whole body of the calcite, and not in separate grains of dolomite.

In this area, therefore, the magnesia, in the magnesian varieties of the crystalline limestone, occurs in some cases as dolomite grains associated with the calcite individuals, while in other cases it replaces a portion of the lime in the calcite.

The calcite individuals which form the limestones of the area are for the most part twinned. They are usually free from other pressure phenomena, but in many localities show between crossed nicols a slightly uneven extinction. In some few places in the area this becomes very pronounced, and the rock develops a striking cataclastic structure, the large calcite grains being not only bent and twisted in a most striking manner, but being actually broken down into an aggregate of much smaller grains, in which ragged remnants of larger calcites, often much elongated in form, lie embedded. This structure, which often gives to the limestones a slabby structure, is strikingly developed in the limestones along the eastern border of the Anstruther batholith, in the townships of Burleigh and Anstruther. A great fault runs through this batholith near its eastern margin, following approximately the line of the eastern contact with the altered sedimentary strata. This probably indicates that the strain to which the rocks along this margin were subjected was extreme, which accounts for the pronounced cataclastic structure which limestones along the line of contact are found to present. These limestones are well exposed on the shore of Big Cedar lake, on lot 12, concession V, and on lot 11, concession IV of Burleigh; also where the road between concessions VIII and IX of Anstruther crosses lot 38 of that township, some fifteen miles farther north.

The limestone at Big Cedar lake is coarsely crystalline, in some cases the individual constituent grains being as much as an inch in diameter. As in the case of the Carrara deposits, it is for

[1] Loc. cit. p. 13.

Fig. 1.—Microphotograph of crystalline limestone from lot 38, concession VIII, Anstruther township, showing strain shadows, twinning lamellæ, and extreme granulation. Between crossed nicols. Magnified 17 diameters.

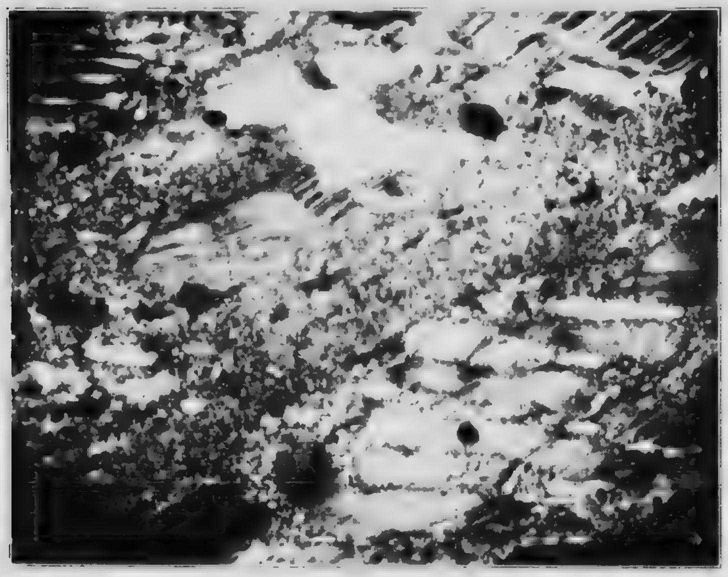


Fig. 2.—Microphotograph of crystalline limestone from lot 38, concession VIII, Anstruther township, showing bending of the twin lamellæ, and extreme granulation. Between crossed nicols. Magnified 17 diameters.

the most part massive and free from any foliation, but along certain lines or bands it presents a very marked parallelism, and cataclastic structure is distinctly seen in hand specimens, large and more or less lenticular and much twisted calcite remnants lying with their longer axes parallel to one another in a fine-grained base derived from their partial destruction. Under the microscope the evidence of this action is most striking. The large remnants are twinned and curved, showing marked strain shadows, and can in many cases be seen to be in the act of breaking down into smaller grains, especially about their margins. In the small grains constituting the base, twinning and strain shadows are also frequently seen, and there is presented a distinct tendency to flattening in the same direction as that in which the longer axes of the large remnants lie. A number of twisted grains of quartz, also showing very marked strain shadows, and in some cases even a marked granulation, are also present in the rock. The occurrences at the other two localities mentioned are identical in character with that just described. (See Plates XLVI and XLVII.)

Another locality where the limestone possesses a marked cataclastic structure is the northwestern portion of lot 29, concession XI of the township of Cardiff. The limestone here in some places is developed as a very fine-grained cream-coloured alabaster-like rock, and presents an appearance different from that seen in the limestone anywhere else in the area. Scattered through this, there are in places twisted remnants of large calcite individuals, like those seen in the Burleigh rock. These present distinct evidence of great pressure and movement, but it is not quite clear whether the fine-grained portion has resulted from the complete granulation of larger calcite individuals by movements in the rock, or whether solution and redeposition has played a part. The rock is referred to in the section dealing with the economic resources of the area.

This cataclastic structure, although not very common, has been observed in the limestones of highly contorted districts in other parts of the world. Vogt[1] describes it in the crystalline limestones of Troviken in Norway, and it is also seen in the marbles of the Swiss Alps, and elsewhere.

---

[1] Loc. cit. p. 14.

An interesting fact in connexion with this peculiar structure is that it can be exactly reproduced by artificially deforming columns of marble under differential pressures at the ordinary temperatures.[1]

In some cases, as in the dolomite of lot 10, concession III of the township of Minden, and in that of lot 5, concession I of the township of Harburn, when thin sections are examined under the microscope, certain of the grains, or certain portions of some of the grains show a peculiar turbidity, while the others are perfectly clear and transparent. This appearance has been observed in the Laurentian limestones of other parts of Canada, and when studied in connexion with that exhibited by the calcite of comparatively unaltered limestones, such as certain beds of the Trenton in the vicinity of Montreal, where it is clearly seen to be derived from fragments of crinoids and other fossils about which clear calcite has been deposited; the outlines of the fossil fragments being frequently by no means sharp, suggests that these limestones also have been derived from the extreme alteration of fossil remains.[2]

The crystalline limestones of the area are very frequently interbanded with thin layers of gneiss, and in some places, especially along the southern margin of the Glamorgan batholith between Irondale and Kinmount, with small bands of quartzite. These represent impure, muddy, and sandy layers in the original calcareous deposit, and are described in another section of this report. They serve to emphasize and bring out in a most striking manner the remarkable plasticity possessed by the limestones under the great pressure to which they have been subjected. While under these conditions, all the rocks of the area have developed a certain plasticity, each bending and flowing, some to a greater and others to a lesser extent before actually breaking. The plasticity of the limestones seems to be almost limitless. They can be seen, when examined in the great glaciated surfaces exposed in many parts of the area, to have accommodated themselves to the most complicated folding and twisting, and in some cases to have been stirred up as one stirs up porridge, by the com-

[1] Adams F. D., and Nicolson, J. T. An Experimental Investigation into the Flow of Marble. Phil. Trans. of the Royal Society of London, Ser. A. Vol. 195, pp. 363-401.

[2] Adams, F. D.—Report on the Geology of a Portion of the Laurentian Area lying to the north of the Island of Montreal. Ann. Rept. of the Geol. Survey of Canada. Part J., p. 66.

plicated movements to which they have been subjected. Under these movements, the associated gneisses, quartzites, and amphibolites are torn to fragments, but limestones flow in between these, and the fragments of these harder rocks can in many cases be seen to have floated away in the moving limestones, as logs float down a stream. Everywhere the limestone accommodates itself to the pressure, and adapts itself to the space which it is obliged to occupy. (See Plates XLIV and XLV.)

The mechanism of this movement, while a question of great interest, and one about which much has yet to be learned, cannot here be discussed. Suffice it to say that it is probably accomplished in the majority of cases by a recrystallization of the calcite, while in some special cases, as for instance some of those described above, it is brought about by cataclastic action, and in still others is due to a movement within the calcite crystals along their planes of translation.

BLUE LIMESTONES.

Certain of the Archæan limestones of the area, as has been mentioned, have survived in a comparatively unaltered condition. These are fine in grain, retaining their original organic pigment, which gives to them a blue or drab colour. The greatest development of these rocks, which may be referred to as the blue limestones, lies in the southeastern portion of the area, in the townships of Tudor and Lake, this being the part of the area which is farthest removed from the great granite batholiths which have forced their way up through sedimentary rocks of the other parts of the area, bringing about a widespread alteration. Going north and west from this district, the limestones become progressively more and more highly altered, still retaining in places, especially in those most remote from the granite intrusions, a bluish colour. In some few places, even within the belts of highly altered crystalline limestones, small portions of the original blue limestone are found to have survived unaltered.

These blue limestones are well seen in the southwestern corner of the township of Lake, where they are in part altered to white marbles. They are dark bluish-grey in colour, weathering brownish, and are usually rather thinly bedded. That they have, even in this comparatively undisturbed part of the area, been subjected to great movement, is seen in the immense number of little folds and contortions which the beds often display, as well as in their slickensided surfaces, and in the little lenses of white

secondary calcite developed along the bedding planes, when slipping movements have been pronounced.

Notwithstanding the fact that these limestones seem to be but little altered when examined in the field, under the microscope they are seen, when highly magnified, to be completely crystalline, consisting of alternated bands of larger and smaller calcite individuals, both containing organic pigment in the form of minute black particles, although this is more abundant in the finer grained portions of the rock. The calcite grains fit into each other along crenulated boundaries, but seldom show evidence of having been submitted to pressure by the development of either strain shadows or twinning. There is a tendency to a flattening in the plane of the bedding in the case of some of the smaller grains, but this is not general, and the bedding is marked chiefly by the colouring matter in the finer grained portions of the rock.

These limestones contain in places grains of quartz, which vary in size with that of the calcite individuals in the bands in which they occur. These have the rounded form displayed by all the silicates in the incipient stages of their growth when developed in the altered limestones, and are evidently secondary. Unlike the calcite they frequently show strain shadows. The small bodies of blue limestone which have escaped alteration, and survive in the middle of belts of highly crystalline limestone, as on lot 28, concession XI of Monmouth, or on lot 27, concession XIV of the same township, or in the body of blue limestone occurring on lot 8, concession VIII of the township of Carlow, have the same structure and appearance. These are, however, rather more massive in their development, and even darker in colour than the limestones from southwestern Lake. They show, however, the same finer and coarser layers of calcite, with occasional grains of silicates, rounded in form and varying in size with the coarseness of grain of the calcite band containing them. These foreign minerals, however, are usually either plagioclase or augite. The calcite individuals, moreover, frequently have smooth rather than crenulated borders, and sometimes show uneven extinction.

The crystalline character of the limestone does not present any obstacle to the rock being considered as of organic origin, for the structure is identical with that seen in many highly fossiliferous limestones which have been sufficiently metamorphosed to bring about an incipient recrystallization of the limestone, and thus to

destroy the structure of any organic materials which entered into its composition.

Over large areas in Tudor, and southeastern Lake, the rocks mapped as blue limestone are more or less impure. On large weathered surfaces this is brought out in a striking manner in the different resistance offered by the several beds to the processes of solution or erosion. Under the attacks of the weather the harder beds stand out in relief, giving a ribbed appearance to the rock, which recalls in a striking manner the structure seen in many of the highly crystalline limestones of the area, where bands of pure, or nearly pure marble alternate with others composed of certain varieties of gneiss or amphibolite. This banded development in the blue limestone formation is well seen along the road between the railway station and the village of Millbridge, in concession IV of Tudor. Here the rocks are well-bedded, the heavier beds alternating with others which are thinly laminated. In some of these the blue colour is pronounced, and they effervesce readily when touched with a drop of acid; while in others the colour is grey rather than blue, and they effervesce only when powdered. Others again, which show but little difference in their deportment with acid, seem to differ considerably in the amount of impurity which they contain. A chemical and microscopical examination of the materials of the various beds shows that some beds consist of limestone, others of magnesian limestone, while still others contain varying amounts of some argillaceous or siliceous material, and that the series, which is apparently comparatively unaltered, really presents every stage in the passage between a rock looking like a clay stone, or a limestone with no impurities except a few of biotite, to a true micaceous gneiss having the pavement structure characteristic of the paragneisses. These various rocks, however, are all fine in grain and very similar in general appearance, and would at first sight be taken for blue limestones, varying somewhat in character in the different beds.

It is clear from both stratigraphical and petrographical considerations that it was from the intense metamorphism of occurrences of this kind that the great volumes of white crystalline limestone, interstratified with immense numbers of thin bands of gneiss or amphibolite which occur in the more highly altered parts of the area, were derived. By such intense metamorphism the organic pigment of the rock would be burned out, or converted into

graphite, and the various constituent bands would increase in coarseness of grain, and would thus, without any change of substance, pass into marbles, gneiss, or amphibolites, as the case might be. Similar occurrences in various stages of alteration are seen also in the southwestern portion of the township of Lake. The stages of the passage of the impure bands into paragneisses and amphibolites has been described in the sections of this report dealing with these two classes of rocks.

The passage of the blue limestone into the white crystalline limestone can be clearly and plainly seen in a great many parts of the area. Even in southwestern Lake, as shown on the Bancroft sheet, there is much of the white crystalline variety associated with the blue limestones described above as occurring at this locality. The passage of one into the other can here be studied with advantage. Also going northeast or northwest from the great development of the blue limestone in Tudor and eastern Lake, the limestones which have been mapped as white crystalline limestones are often bluish in bands and streaks, or have a pale bluish tinge throughout their mass. There is really a gradual transition rather than a sudden passage from the blue to the white limestone, although it is impossible without introducing great complexity of colouring to show this on the map. Where in the townships of Monmouth and Glamorgan small areas of the blue limestone are shown enclosed in great developments of the white crystalline variety, the gradation of one into the other is clearly seen. No suggestion of an infolding of newer limestones can be entertained. The white crystalline limestones have resulted from the alteration of the blue limestones, of which in these cases small bodies have survived. The locality in which the relation of these small bodies to the enclosing white limestones can best be studied is on a private road which crosses the north end of lot 28, concession XI of Monmouth, and connects the post road with the Irondale, Bancroft and Ottawa railway track. The limestone here is interstratified with thin layers of micaceous schist and fine-grained quartzite. It is for the most part the ordinary white crystalline variety, but in it are numerous small bands, up to six inches in thickness, of the blue limestone, fine in grain and identical in character with that found in the township of Lake. The dark blue layers run with the banding of the rock, which is here evidently the original stratification along which the alteration has proceeded, gradually

invading the rock along these lines, and eventually leaving only little bands, sometimes mere streaks of the limestone in an unaltered condition. Single hand specimens showing all stages of the alteration can be easily secured. Similar phenomena are well represented in many of the occurrences of limestone in the valley of the Jack and York rivers, where all stages of the metamorphism may be studied

In how far the changes observed in these limestones are to be attributed to what is generally known as dynamic metamorphism, and to what extent they may be said to be the products of contact metamorphism, it is difficult to decide. Orogenic movements may have led to the development of the batholiths, which in their turn were the sources of widespread contact metamorphism; or the uprise of the batholiths may have been the sole cause of deformation and metamorphism. Here at these great depths all metamorphic forces probably acted simultaneously, but it would seem that the agency of heat played a very important rôle, and that thus the character of the metamorphism displayed in the various parts of the area is essentially the same, although its intensity varies greatly, reaching a maximum in the immediate vicinity of the batholiths themselves.

What has been referred to and described as the Tudor eozoon was collected in 1866 by Mr. H. G. Vennor, of the Geological Survey,[1] from a heap of boulders piled in a field on lot 15, east of the Hastings road in the township of Tudor. In this vicinity the rock in place is the prevailing unaltered bluish-grey limestone, often interstratified with narrow bands or folia of micaceous shale (evidently an unaltered representative of the abundant paragneiss), an[illegible]hibolite. These interlaminations, in their more minute representatives, simulate the banded structure of eozoon. Moreover, even in the limestone itself, alteration and accompanying recrystallization is widespread, so that alternations of white and blue limestone are presented by the various exposures. A loose specimen representative of this interbanding of altered and unaltered limestone was collected as resembling the banded structure of eozoon. It is regarded as more than significant that, although much of the material representative of the supposed fossil is very

[1]Ann. Rep. Geol. Surv. Can. 1866-69, p. 159; Quart. Jour. Geol. Soc., Lon., August 1867; Can. Naturalist, Vol. III, No. 4; J. W. Dawson, Dawn of Life, p. 110.

little altered, any of the minute structures exhibited were much less perfectly preserved than the type specimens which were collected at localities where the rock metamorphism was extreme.

The serpentinous limestone occurring to the south of the village of Bancroft also in places presents a banded character suggestive of eozoon.

The only other locality where a rock having the appearance of eozoon was discovered is on lot 13, on the line between concessions IX and X of the township of Wollaston. Here, on the north side of the road, a ridge of rock rises from the drifted country, and is found to consist largely of a finely foliated white pyroxenite, with occasional little layers of serpentine. Although the rock probably represents a small band of extremely altered limestone, it now contains but very little calcite, and when examined under the microscope is found to be entirely devoid of any of the more minute structures characteristic of eozoon

Hills of nepheline syenite, two miles east of Bancroft, Dungannon township

THE NEPHELINE AND ASSOCIATED ALKALI SYENITES.

These rocks have an especial economic interest attaching to them, owing to the fact that in association with them are found all the occurrences of corundum which have recently attracted so much attention to this district.

DISTRIBUTION.

If, on the Haliburton map sheet accompanying this report, a straight line be drawn from the centre of the township of Snowdon to the northeast corner of the map, all the occurrences of nepheline syenite, or of the peculiar alkaline type of syenite which is associated with this rock, will be found to lie to the south of this line. Furthermore, all the occurrences of this rock in the area are included within the bounds of the Haliburton sheet, with the single important exception of the Methuen band. This occurrence, however, as well as the more southerly of those above mentioned, are embraced by the Bancroft map sheet. Within the triangular area bounded as above described these syenites are irregularly distributed, for the most part in isolated bodies, through the townships of Glamorgan, Monmouth, Harcourt, Wollaston, Faraday, Dungannon, Monteagle, Carlow, Raglan, Radcliffe, Brudenell, Lyndoch, Sebastopol, and South Algona.

GEOLOGICAL RELATIONS.

The nepheline and associated alkali syenites are found either along the actual contact of the granite and the limestone, or in the limestone itself near the granite contact. There is only a single exception to this in the area under discussion, namely, the nepheline syenite mass in the township of Methuen, which occurs between a great granite intrusion and the body of amphibolite, containing a few small bands of limestone.

They are intruded into the crystalline limestones and associated sedimentary rocks of the Grenville series on the one hand, and, as far as can be determined at the several points where they

are well exposed, they pass over into the fundamental gneiss on the other hand. Elsewhere, however, dikes of the nepheline syenite or associated alkali syenites can be seen to cut the fundamental gneiss. A careful study of the whole area shows that the nepheline syenite and its associated alkali syenites represent a peripheral differentiation phase of the granite (fundamental gneiss), and that in the few cases where these rocks are seen to cut the fundamental gneiss they are of the nature of dikes of differentiated material intruded into a more acid phase of the same magma which was already consolidated very much in the same way as in the case of ordinary granite pegmatite, dikes are found representing the last product of consolidation of a common magma.

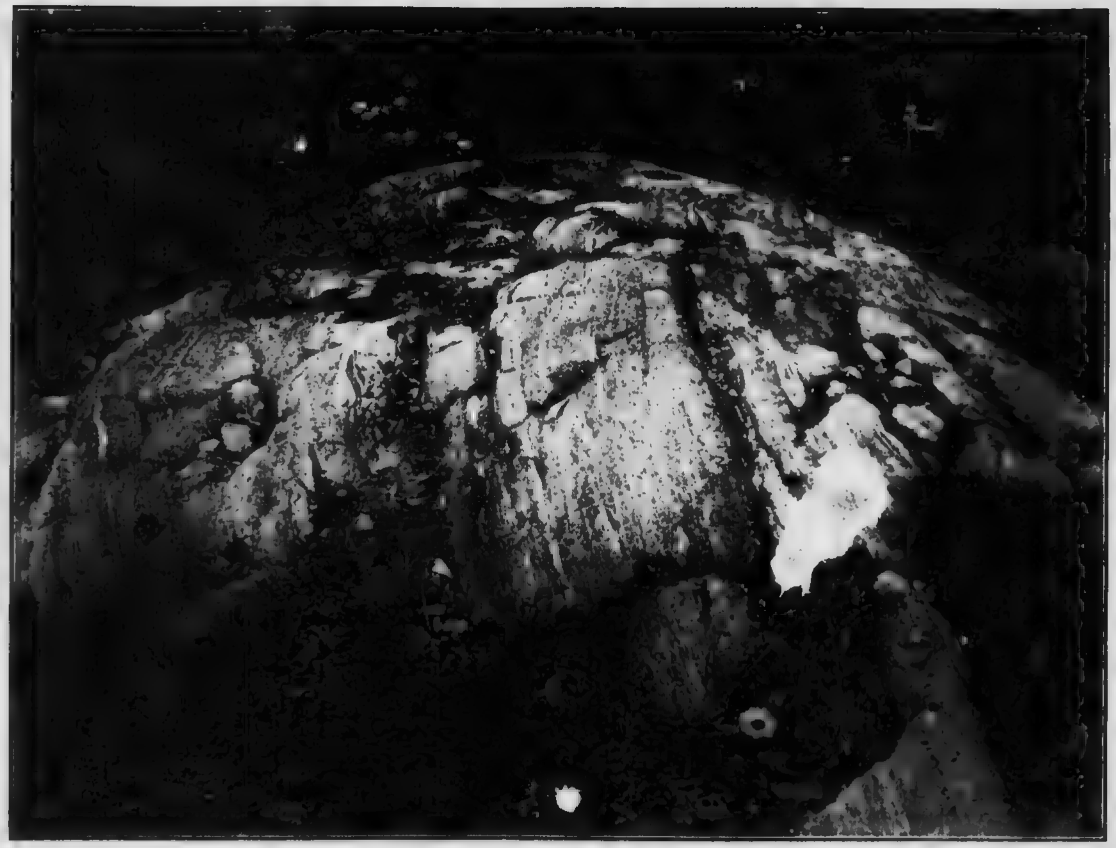
GENERAL PETROGRAPHICAL CHARACTER.

It would far exceed the scope of the present report to describe in detail the exact mineralogical composition of these syenites at all the various localities where they are exposed, for their extreme and rapid variation in composition is one of the most noteworthy features of their development. In fact, too much emphasis can hardly be given to this fact, for no other rocks show an equally great diversity of types within such short distances. It is quite possible to obtain hand specimens from the same exposure, and even from contiguous bands, which exhibit such a wide difference in their mineralogical composition as to be classed as separate and distinct types of rock. All these, however, are differentiation products of one highly alkaline and aluminous magma, representing one phase of plutonic activity. They belong to one petrographical province: nevertheless, for purposes of convenience of description, they may be considered as divisible into several groups, although it must be understood that no arbitrary lines exist in nature between these respective subdivisions.

1. The Nepheline Syenite.
2. Rocks of the Urtite and allied groups.
3. The White Alkali Syenite.
4. The Red Alkali Syenite.

1. *The Nepheline Syenite.*—This is made up essentially of an acid plagioclase, usually albite, with nepheline and biotite (lepidomelane), hornblende, or pyroxene. Orthoclase, microcline,

PLATE XLIX.



Nepheline syenite showing regional foliation. Near York River bridge, lot 13, concession XII, Dungannon township.

and microperthite are occasionally found, but when present rank merely as accessory constituents.

2. *Rocks of the Urtite and allied groups.*—The nepheline syenite presents extreme variations in the relative proportion of its constituent minerals, passing by a decrease in the amount of plagioclase present into rocks composed exclusively of nepheline and ferro-magnesian minerals, or into varieties composed on the one hand almost exclusively of nepheline (Monmouthite), or, on the other hand, into very basic varieties composed almost exclusively of iron-magnesia constituents, and approaching jacupirangite in composition. Elsewhere the plagioclase increases in amount, and the rock passes into an alkali syenite of one of the following types.

The rocks of groups 1 and 2, in addition to their essential constituents, almost invariably contain a certain amount of calcite. Scapolite is a frequent constituent. Some of the less frequent accessory constituents are garnet, sodalite, cancrinite, fluorite, muscovite, corundum, magnetite, pyrite, sphene, zircon, apatite, spinel (automolite), graphite, and eudialite.

3. *White Alkali Syenite.*—This differs from the nepheline syenite in the occurrence of nepheline merely as an accessory constituent, or by the entire absence of this mineral. The rock is thus composed of an acid plagioclase and the ferro-magnesian constituents, the latter being present usually in very subordinate amount.

4. *Red Alkali Syenite.*—This rock is distinguished at once from the preceding syenite by its pinkish or reddish colour. It also contains plagioclase, usually albite, as the predominant feldspar, but orthoclase and microcline are usually present, and are relatively more abundant than in the white syenite. Occasionally a little nepheline occurs, but when found is usually decomposed to a reddish or pinkish gieseckite. Magnetite in small irregular crystals and grains is usually present. Biotite is the iron-magnesian constituent, and is, as a general rule, present in very subordinate amount. When specimens are examined by the unaided eye, quartz seems to be entirely lacking, but an examination of thin sections under the microscope often reveals this mineral, sometimes in no inconsiderable amount.

The rocks of these several groups pass into one another by imperceptible gradations. The magmas of all four types were in

places supersaturated with alumina, the whole of this excess crystallizing out as free alumina in the form of corundum. In those varieties of nepheline syenite which are unusually rich in nepheline, and in the rocks of the Urtite group, the corundum is only developed when the iron-magnesian minerals do not occur in any appreciable amount.

Intimately associated with the rocks of these several types, and forming part of the same igneous complex, are certain abnormally coarse phases which are their pegmatitic equivalents. These may occur as parallel or intercalated bands, or they may cut across the foliation of the rock in the form of dike-like masses. The contact of these pegmatites with the parent or normal plutonic rock is sometimes quite sharp, especially in the case of those which intersect the foliation. They usually, however, present a rather abrupt, though quite perceptible transition into the ordinary medium-grained type. The nepheline syenite pegmatite is usually composed altogether of nepheline and albite. Sometimes very large individuals of biotite, and occasionally of hornblende, apatite, and magnetite, are present. The pegmatitic form of the red syenite is made up almost exclusively of microperthite, consisting of an irregular intergrowth of orthoclase and albite.

The term syenite, as applied to the nepheline syenite, at least in the northeastern portions of the syenitic band, is somewhat of a misnomer, for plagioclase, varying from albite through oligoclase to andesine, is the prevalent and often the only feldspathic constituent. In a paper[1] announcing the discovery of these occurrences in the townships of Dungannon and Faraday, the statement was made that, "If the distinctive character of the nepheline syenite named Litchfieldite by Bayley be the replacement of the orthoclase by albite, this rock is a more typical Litchfieldite than that from the original locality. The propriety of defining nepheline syenite as a rock composed essentially of nepheline and an alkali feldspar, instead of one composed of nepheline and orthoclase, is rendered evident, as otherwise it would be necessary to classify this rock as a theralite, from typical specimens of which it would differ greatly in composition."

These various rocks, while sometimes quite massive, usually possess a more or less perfect foliated structure, which in many places presents a schistose development. They vary in texture

[1] Adams, F. D.—American Journal of Science. Vol. xlviii, 1894, p. 15.

Dike of nepheline syenite pegmatite, cutting nepheline syenite parallel to the foliation, lot 25, concession XIV, Dungannon township

from medium to coarse-grained, while the pegmatitic phases sometimes present nepheline and plagioclase individuals as much as a yard in diameter. (See Plates XLIX, L, LII, and LIX.)

At times magmas of all four of the above subdivisions have become supersaturated with alumina, the whole of this excess crystallizing out as free alumina in the form of corundum. In the nepheline syenite and urtite, especially those varieties which are abnormally rich in nepheline, corundum is only developed when the iron-magnesia minerals do not occur in any appreciable amount. Intimately associated with rocks of these three subdivisions, and forming part of the same igneous complex, are certain abnormally coarse phases, which are regarded as their pegmatitic equivalents. These may occur as parallel or interfoliated bands, or they may cut across, making considerable angles with the foliation. The contact of these contemporaneous veins with the parent or normal plutonic is sometimes quite sharp, especially those developments which intersect the foliation; but usually there is a rather abrupt, though quite perceptible transition into the ordinary grained type.

The rock is, as a rule, remarkably fresh and unaltered, possessing a true hypidiomorphic granular structure. Evidences of pressure, even in some of the most pronouncedly foliated or schistose varieties, are extremely rare. In occasional instances, however, some of the feldspars show rather pronounced strain shadows, and curved or slightly dislocated twinning lamellæ. Sections moreover of the rock comprising the narrow part of the band, crossing the Monck road in Faraday township, show quite pronounced granulation and cataclastic structure.

The relations of the constituent minerals, especially the feldspathoid species, do not show the same regular and definite order of succession as is usual in most rocks which have crystallized from a molten magma. In general, however, it may be stated that after the crystallization of such minerals as apatite, zircon, sphene, corundum, and magnetite, individuals of which usually possess rather good crystal outline, the hornblende and biotite were formed. Both of these minerals, and especially the hornblende, exhibit many sharp and distinct crystallographic boundaries. Plagioclase came next in order, while the remaining interspaces were filled with potash feldspars or nepheline. In the texture of the rock, in the majority of instances, nepheline apparently plays

the same part as quartz in an ordinary granite. Garnet, which is a very frequent and often abundant accessory constituent, is distinctly later than all of these constituents. Sodalite and cancrinite are also distinctly later, filling cracks and fissures.

On the other hand, there have been noticed many grave exceptions to this general order of crystallization, such as the inclusion of rounded individuals of nepheline and microcline in the plagioclase, and of plagioclase and nepheline in the hornblende. Again, albite has frequently been noticed apparently forming poikilitic intergrowths with hornblende, such included individuals often having direct connexion, and more or less distinct optical continuity, with certain mantles or borders (reaction rims?) which sometimes surround the hornblende, separating individuals of this mineral from the other constituents of the rock. There is, moreover, undoubted evidence of very pronounced magmatic corrosion and trespass, due apparently to progressive changes in the physical constitution and composition of the magma. This is shown in a most marked manner by the almost invariably rounded or curved outline of the various constituent minerals, extending down even to the first formed apatites, zircons, etc. The shells or mantles of muscovite which often enclose the individuals of corundum are also distinctly and clearly explicable by reason of the increased acidity and hydration of the later stages of the magma.

Such irregularities, however, do not invalidate the general testimony as regards the age relations of the constituent minerals furnished by the study of a large number of thin sections under the microscope. It is the opinion of Holland[1] that "these contradictions and apparent oscillations in the order of crystallization are due to disturbances during consolidation." In this regard these syenites present similar conditions, although in a minor degree, to crystalline schists and certain eruptives which have undergone more or less complete recrystallization.

The nepheline syenites, and the associated alkali syenites, as has been mentioned, occur almost invariably on the borders of the granite batholiths where these cut through crystalline limestone.

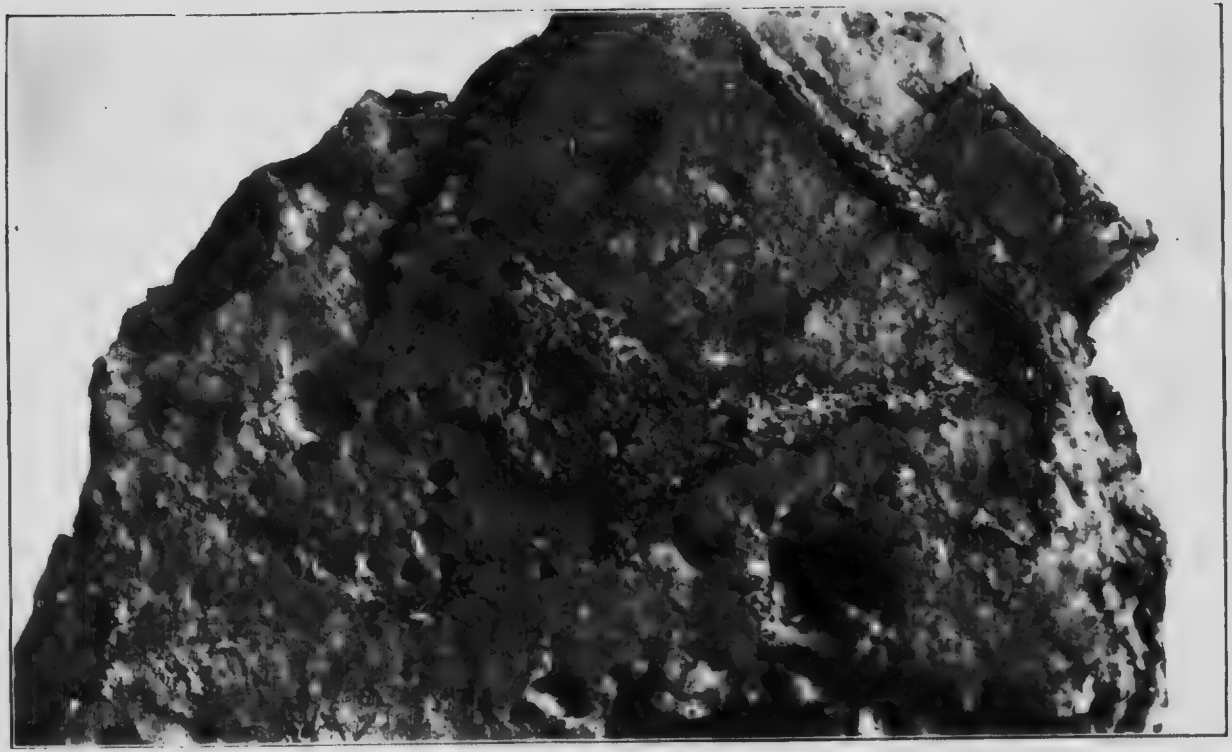
When the actual contact of the two rocks is well exposed, large individuals of nepheline, biotite and other constituents of

[1] Mem. Geol. Surv. India. vol. xxx, part 3, 1901. p. 194.

PLATE LI.

Microphotograph of nepheline syenite from lot 32, concession VI, Glamorgan township, showing biotite, nepheline, and microcline. The thin section shows two grains of calcite, one lying between the biotite and nepheline, and the other enclosed in the microcline. All the minerals are absolutely fresh and show no trace of decomposition products. Magnified 66 diameters.

PLATE LII



Nepheline syenite pegmatite showing characteristic weathering, lot 30, concession IV, Glamorgan township. Nepheline with albite standing out on weathered surface. The cavities in the surface of the nepheline are caused by inclusions of calcite which have weathered out. Magnified two-thirds.

the syenite can be seen to have developed in the limestone all along the margin of the nepheline syenite body, while masses of the limestone, great and small, can be found scattered through the nepheline syenite along the contact. These masses, furthermore, are evidently in process of replacement by the magma, the various constituents of the nepheline syenite growing into them. They thus become gradually reduced in size, and eventually survive merely as separate, irregularly rounded grains of calcite, often enclosed in single individuals of perfectly fresh nepheline, hornblende, or other minerals of the nepheline syenite, or lying between these, with the form of the latter impressed upon them on every side. (See Plates LI and LII.)

Every stage of the passage from the solid limestone to the separate calcite grains enclosed in the constituent minerals of the nepheline syenite can be distinctly traced, while the latter is at the same time fresh and free from decomposition products. This is well seen in the cutting made for the Central Ontario railway where it enters the village of Bancroft. In some cases an additional proof of the derivation of the calcite from the adjacent limestone is afforded by the fact that the calcite grains enclosed in the nepheline syenite show the twisting and strain shadows to be observed in the constituent parts of the invaded limestone, while the minerals of the nepheline syenite which enclose them are free from all signs of pressure. The calcite in the syenites is undoubtedly foreign to the magma and represents inclusions of the surrounding limestones. In the case of the only important body of nepheline syenites which does not have limestone as a wall-rock, namely, the occurrence in the township of Methuen, calcite is very rarely found in the rock, and when it does occur, it is in very small amount, and the mode of its occurrence is entirely different from that above described, and is such as to indicate that the mineral is probably secondary, or a later infiltration.

The presence of calcite has been noted in other occurrences of nepheline syenite. These are, like those of the area at present under discussion, associated with ancient metamorphic rocks, and the calcite in them is believed to be primary, by the investigators who have studied them. The occurrences in question are the nepheline syenites of the Sivamalai series of India[1], and that of the

[1] Holland, T. H.—The Sivamalai Series of Elæolite Syenites and Corundum Syenites in the Coimbatore District, Madras Presidency. Mem. Geol. Survey of India. Vol. xxx. part 3, 1901. p. 197.

Island of Alno[1] in Sweden. A similar association has been noted in the occurrences at Kussa in the Ural mountains[2], and in the nepheline rocks of the Kaiserstuhl in Baden.[3]

Concerning the calcite in the Indian occurrences, Holland says:—"The calcite occurs in granular crystals, with apparently as much right as any of the others to be considered a primary constituent. The crystals form isolated granules, and there are no signs of secondary decomposition—the low silica percentage in this group of rocks removes the chief theoretical difficulty to its crystallization from a molten magma as a normal constituent of an igneous rock." The Alnö rock contains large masses of crystalline limestone, as well as scattered granules of calcite and micropegmatitic intergrowths of calcite, with nepheline, ægrine or feldspar, and Högbom believes that the limestone has been fused in the magma without decomposition, and was, during the process of solidification, crystallized out of the magma in precisely the same way as the other minerals. In neither of these cases does limestone now occur in the immediate vicinity of the syenite, but it may, especially in the latter case, have sunk down into it from overlying beds, since removed by erosion.

This is also considered by Graeff to be the true explanation of the origin of the limestone inclusions in the Kaiserstuhl occurrence. Of the crystalline limestone associated with the Kussa nepheline syenite, Arzruni says that its "austreten unaufgeklart geblieben ist."

Mineralogical composition.—As in their general character, the minerals which in varying proportions constitute the several rock types under consideration are essentially identical, an account of these will here be given in order that unnecessary repetition may be avoided in the description of the several occurrences. They are the following:

---

[1] Högbom, A. G.—Ueber ü das Nephelinsyenitgebiet auf der Insel Alnö. Geol. Foren i. Stockholm Forh. Bd. 17. Heft 2, 1895, s. 118. Also Abstract in Min. Mag., vol. xi. (1897), p. 250, and Rosenbusch Mikr. Phys. (1896), pp. 169 and 171.

[2] Arzruni, A.—Die Mineralgruben bei Kussa und Miass. (In the Livre Guide for the Ural Excursion of the International Congress of Geologists, St. Petersburg Meeting, 1900.)

[3] Graeff.—Zur Geologie des Kaiserstuhlgebriges. Mitt. d. Grossberg. Bad. Geol. Landesanst. Bd. II, 1892.

Knop.—Der Kaiserstuhl in Breisgau. Leipzig, 1892; also Högbom, A. G. (loc. cit.)

Nepheline.	Sphene.
Sodalite.	Tourmaline.
Cancrinite.	Spinel.
Feldspar.	Eucolite.
Scapolite.	Molybdenite.
Biotite.	Apatite.
Hornblende.	Magnetite.
Muscovite.	Pyrite.
Corundum.	Pyrrhotite.
Calcite.	Chalcopyrite.
Garnet.	Graphite.
Zircon.	

Nepheline.—It has been customary to restrict the use of the term nepheline to the colourless and glassy varieties usually found in the younger volcanic rocks, reserving the name elæolite for the varieties found in the plutonic rocks, which, as a rule, exhibited a certain oily lustre of which this name is descriptive. In describing these Ontario occurrences, however, this second term is not required; the nepheline has almost everywhere a lustre which is essentially vitreous.

As a rule the mineral is quite fresh and glassy, breaking with a sub-conchoidal or uneven fracture. The freshly broken fragments are often distinguishable with difficulty from the plagioclase, with which it is so intimately associated. It varies from almost colourless to white, or very pale grey and translucent, where exposed to the action of the weather. Very often it possesses a beautiful pale salmon pink colour, which on inspection is seen to accompany an incipient decomposition of the mineral. A progressive increase in this alteration is characterized by a gradual deepening of the tint until a bright brick red colour is assumed, representing the extreme stages in the decomposition and hydration of this mineral. The resultant products in the primary stage are chiefly minute scales of muscovite, with very brilliant double refraction, the process extending from certain cracks, and from the margin of the individual, or forming halos around certain inclusions. Some of the individuals are more or less turbid and opaque as a result of decomposition. In the more highly coloured phases of the mineral an aggregate resembling gieseckite in composition and appearance is produced, with accompanying very brilliant aggregate polarization. It is usually comparatively

free from inclusions, although sometimes hornblende biotite, calcite, and even feldspars occur enclosed. The hardness, according to Dr. Harrington[1], of the nepheline occurring at York river is nearly 6. The specific gravity at 17° C. 2·625 as determined with the bottle, and 2·618 by suspension with a hair. Before the blowpipe it fused quickly at about 3·5 to a colourless slightly vesicular glass. An analysis of this nepheline by Dr. Harrington gave the following results (under I). For comparison, an analysis of the yellow variety of nepheline of Coimbatore, Madras, India, is given under II.(2).

	I	II
SiO_2	43·51	43·35
Al_2O_3	33·78	34·32
Fe_2O_3	0·15	1·02
CaO	0·16	0·82
MgO	tr.	.
K_2O	5·40	5·52
Na_2O	16·94	14·62
Loss on ignition	·40	0·75
	100·34	100·40

One marked feature of the nepheline syenites everywhere throughout the area, is the peculiar appearance presented by the nepheline on the weathered surface of the rock. When a weathered surface is examined, each grain or individual of nepheline will invariably be found to be represented by a depression. At the bottom of this the nepheline grain can be seen with a smooth rounded surface, as if it had been partially dissolved away, the feldspars and iron-magnesia constituents standing up above its surface on all sides. The surface of the nepheline is coated with a mere film of decomposition products, and is of a faint bluish grey colour, the feldspar weathering chalk white, and on breaking the rock open the nepheline appears to be perfectly fresh. Evidently the nepheline is destroyed much more readily by the weather than the other constituents of the rock, and the alteration products are of such a character that they are at once removed, leaving the surface of the mineral fresh and hard. This peculiar method of weathering makes it possible to determine the presence or absence of nepheline

[1] Amer. Jour. Sc. Vol. xlviii (1894), p. 17.
[2] Mem. Geol. Surv. Ind. Vol. xxx, part 3 (1901), p. 187.

in any specimen of the syenite, from a careful inspection of the weathered surface of the rock alone. In fact, its presence can be quite as certainly determined in this way as by means of chemical tests in a microscopical examination. This simple method has, furthermore, the advantage that it can be applied to large areas of rock surface.

Sodalite.—This mineral was observed at a large number of widely separated localities along the great belt of these syenitic rocks, especially in the townships of Glamorgan, Faraday, Dungannon, Monteagle, Raglan, Brudenell, and as far as Clear lake near the northeast end of the belt.

It usually occurs in ill-defined, irregular masses and patches, usually of comparatively small size, in the nepheline syenite, especially those portions which are abnormally rich in nepheline. It is also developed along and in the immediate vicinity of certain cracks and fissures in the nepheline, with no sharp line of division between the two minerals, the bluish colour gradually fading in passing outward, to the white or pale greyish nepheline. In thin sections under the microscope it is seen to occur in irregular strings or vein-like forms cutting across and among the other constituents. In certain portions of the area, however, it occurs in very large masses, notably on lot 25, concession XIV of Dungannon. Here it appears to have had a pneumatolitic origin, although occurring very intimately associated with the foliated monmouthite, which constitutes the country rock. It occurs in very irregular, more or less lenticular masses, associated with nepheline, albite, magnetite, lepidomelane, a black hornblende, apatite, and coarsely crystalline masses of calcite. In these irregular vein-like masses, vugs are frequently seen, consisting of open spaces lined with large crystals of the various minerals above mentioned, with the exception of the calcite. These when followed out can be seen to represent large enclosed masses of coarsely crystalline calcite, into which the other minerals have grown with perfect crystalline terminations. The remaining calcite having been removed by solution, the crystal-lined cavity is produced, although elsewhere the calcite aggregate still remains, with the growing faces of the minerals embedded in it. (See Plate LIII).

The presence of the sodalite on lot 25, concession XIV of Dungannon, has been proved over a length of some 250 feet, with a width of from 40 to 50 feet, and it is stated to be even

more extensive than present developments have shown. Sufficient quarrying has, however, been done to prove this occurrence to be of distinct economic importance, as it is quite possible to secure blocks of sodalite weighing several tons. In 1906 a shipment was made of 130 tons of what was considered suitable material to be used in the decoration of the residence of Sir Ernest Cassell, in Park Lane, Hyde Park, London, England. This property has been known as the Princess Quarries, although a company has not yet been incorporated. It is stated to be the intention of the owners to install a complete plant, not only for quarrying the sodalite with channelling machines but for sawing it into slabs of suitable thickness. Other exposures showing large masses of beautifully coloured sodalite also occur on lots 25 and 29, concession XIII of Dungannon. At the first mentioned locality, preliminary development work, consisting of stripping and some blasting, has shown the presence of several large patches of the sodalite. At Craigmont, in Raglan township, and on lot 34, concession V of the township of Brudenell, patches of deep blue sodalite occur in a nepheline syenite, made up in addition to this sodalite of a beautiful pale salmon pink nepheline and grey plagioclase, the association producing a rock which has a very pleasing effect. The colour in this mineral varies from a very dark cobalt blue to very pale bluish, the colour fading rapidly when exposed to the action of the weather. It is susceptible of a high polish, and is eminently suitable for inside decorative work. It is often associated with more or less magnetite and biotite, and shows veinlets of reddish and whitish feldspar, which was shown on analysis by Dr. Harrington to be orthoclase. A sample in the museum of the Geological Survey shows a crystal of hastingsite several inches in length, and perfectly terminated, completely enclosed in the sodalite. Most of the material is compact, with a multitude of very fine cracks, which may be due to the shocks of blasting. The specimen selected by Dr. Harrington for analysis showed distinct dodecahedral cleavage, and vitreous lustre. It is translucent, and often sub-transparent in ordinarily thin fragments. It has usually a very distinct conchoidal and somewhat uneven fracture. Its hardness is about 5·5. Heated in a closed tube the sodalite became perfectly white, while before the blowpipe it fused easily with intumescence to a colourless

PLATE LIII.

Crystals of nepheline and albite from miarolitic cavity in nepheline syenite, lot 25, concession XIV, Dungannon township. (Block measures 26 inches in length.)

glass. Under I is an analysis of the sodalite from lot 25, concession XIV of Dungannon, by Dr. B. J. Harrington.[1] Under II analysis of sodalite from Dungannon by L. McI. Leigher, and G. J. Volckenning.[2]

	I	II
SiO_2	36·58	37·34
Al_2O_3	31·05	31·25
FeO	·20	......
Na_2O_3	24·81	25·01
K_2O	·79	·74
CaO		·38
Cl	6·38	6·79
SO_3	·12	.....
H_2O	·27	......
Insoluble	·80	.....
	101·50	101·51
Deducting O=Cl	1·55	....
	99·95	...
Specific Gravity =	2·295	2·303

Cancrinite. This mineral was first detected in Canada by Dr. Harrington, who found it in the nepheline syenite of Montreal and Belœil in the province of Quebec, and thus writes of its occurrence at these localities.[3] "Some of the syenites are traversed by segregated veins, which contain the minerals of the enclosing rock, as well as a number of additional species. One of these has afforded both acmite and cancrinite in such quantity as to be readily available for analysis." In the nepheline syenites of Ontario, it usually can only be distinguished by the assistance of the microscope. It occurs in irregular grains, or rude radial aggregates, whose outlines are dependent on the surrounding minerals. It is, usually at least, in immediate association with the nepheline, and sometimes forms a narrow border more or less completely surrounding the grains of this mineral. It also occurs in cracks or fissures traversing the nepheline. Under the microscope it is transparent and colourless, and altogether free from inclusions or alteration products.

Cancrinite was noticed in considerable amount in the nepheline syenite where it crosses the Monck road in Faraday township, and it also appears in several of the thin sections of the syenite

[1] Am. Jour. Sc. Vol. xlviii., 1894, pp. 17 and 18.
[2] Am. Jour. Sc. Vol. xlix., 1895, pp. 465-466.
[3] Trans. Roy. Soc. Can. Vol. 1, sect. iii, 1882-83, p. 81.

made from specimens of the syenite obtained about two miles east of Bancroft. On lots 25, concessions XIII and XIV of Dungannon, the cancrinite was found in small irregular masses, with rather ill-defined boundaries, and so intimately associated with the nepheline as to be separable only with extreme difficulty. The nepheline here is usually present in large cleavable masses, with a slightly oily lustre. The cancrinite is translucent, of a pale citron-yellow colour, gradually fading on exposure to the weather. It has a subvitreous and somewhat greasy lustre. The alteration from nepheline seems undoubted, the cleavage planes, in contiguous masses or areas, being common to both, while the boundaries between the two are rarely, if ever, sharp or distinct.[1]

Feldspar.—Plagioclase, varying in composition from albite, through oligoclase to andesine, is the prevailing feldspar in all of these nepheline and associated syneites, and of these feldspars, albite with a small percentage of lime is the most common.

All of these plagioclases are beautifully fresh and clear; occasionally, however, they are somewhat turbid on account of the development of minute scales of micaceous decomposition products. Some of the individuals have broad and sharply defined twinning lamellæ, others very narrow and often indistinct ones. The specific gravity, determined on two fragments from the very coarse-grained variety of the rock near York river, is 2·6207 and 2·625, while in a separation of the rock from lot 25, concession XIV of Dungannon, it was found to be not greater than 2·623. The specific gravity of the fresh oligoclase from the syenite was about 2·64, although some of it which had undergone partial alteration was considerably lighter. The andesine, which is the feldspathic constituent of the nepheline syenite from lot 12, concession XV of Dungannon, was determined by heavy solution on fine fragments to be 2·668. An analysis of this feldspar is given on page 323.

A noteworthy feature in connexion with the development of the feldspar is the frequent occurrence of a thin mantle of plagioclase (albite), more or less completely surrounding individuals and even aggregates of hornblende, and separating these from the surrounding and more abundant nepheline. It has also been noticed as a border surrounding calcite, and between this mineral

[1] Can. Rec. Sc. Vol. vii, No. 4, 1896-97.

and the nepheline. This bordering zone of plagioclase is rather variable in width, but shows very marked optical continuity over long distances, in this respect also being in close agreement with similar feldspathic material which occurs filling up the various inequalities in the hornblende individuals formed as a result of the imperfect crystallographic development of this mineral and also with inclusions of feldspar in the midst of the hornblende. In some respects this phenomenon resembles certain reaction rims, and is thus explained by Holland[1]; but what seems a more reasonable explanation of the Ontario occurrences is that as the plagioclase succeeded, and to a certain extent overlapped the crystallization of the hornblende, it would have been attracted to such centres of crystallization as had already been formed by the solidification of the earlier and more basic mineral. This curious occurrence is well illustrated in certain of the hornblende varieties of the syenite exposed at the dam at Bancroft, and at Egan chute on the York river. The larger crystals of corundum occurring in the nepheline-rich variety of the syenite at Craigmont are also frequently surrounded by a zone of plagioclase, separating the former mineral from the prevailing nepheline.

Microcline is rather unusual in the nepheline syenite, and much of it presents a somewhat indefinite and distorted mesh, which is not distinctive. Much of the microperthite has the very fine and interrupted twinning lamellation characteristic of anorthoclase, with which it is probably identical. Most of what has been considered to be orthoclase in this district also shows quite a perceptible albitic intergrowth, the potash feldspar being, however, predominant.

A white and reddish mineral, which proved on analysis by Dr. Harrington to be orthoclase, fills certain little cracks traversing the sodalite on lot 25, concession XIV of Dungannon. It is mostly dull, but in places shows cleavage surfaces with a pearly lustre. The reddish portions probably owe their colour to the decomposition of pyrite, occasional grains of which still remain. The specific gravity at 18° C was found to be 2·555, and analysis gave the following percentage composition:—

[1] Mem. Geol. Surv. Ind. Vol. xxx, part 3, 1901, pp. 190–191.

SiO_2	63·00
Al_2O_3	18·93
Fe_2O_3	·59
CaO	·08
MgO	·09
K_2O	12·08
Na_2O	[illegible]·67
Loss on ignition	1·00
	99·44

Scapolite.—This mineral is a frequent and often abundant constituent of the nepheline syenite, occurring in clear colourless grains, which meet the accompanying nepheline and felspar grains with a perfectly sharp outline, and no hint of alteration or weathering. Basal sections present the usual double set of cleavages crossing at right angles, while sections parallel to the prismatic zone show a single set of cleavages with parallel extinction. It is uniaxial and negative. The double refraction is much stronger than in the nepheline and feldspars, the interference colours being red, blue, and yellow. In this it resembles cancrinite, from which it can generally be distinguished by its habit, the cancrinite usually filling in cracks and the small interspaces left after the crystallization of the other constituents. It can also be distinguished by treatment with acid, as scapolite remains unaffected, while nepheline and cancrinite are attacked, and when subsequently treated with fuchsine become strongly coloured.

Biotite. This is the prevalent iron-magnesia constituent of these rocks, but it is usually present in subordinate amount. It occurs in small scales and plates, some of which exhibit good crystal boundaries. The hand specimens show an almost black mica, which has usually a distinctly greenish colour in transmitted light. The thin sections under the microscope have a very strong pleochroism, from pale greenish yellow to very deep almost opaque greenish brown. Basal sections are distinctly biaxial, but with a very small axial angle. In some of the coarser phases of the rock, as well as occupying certain miarolitic cavities, as in the northwest corner of Faraday, some of these biotite crystals are very large and well formed.

The dark brown or black lepidomelane present in the essexose of lot 16, concession IX, of the township of Monmouth (p. 2[illegible]2), was isolated by means of a Wetheral Electric Separator, followed by the use of the Thoulet solution, and was analyzed by J. E. Egleson, M.Sc., of McGill University. It was found to have the following composition:[1]

SiO_2	31·48
TiO_2	2·50
Al_2O_3	17·23
Fe_2O_3	[illegible]
FeO	27·96
MnO	1·67
CaO	1·33
MgO	2·[illegible]
K_2O	4·17
Na_2O	1·68
Li_2O	0·00
Water (combined)	3·94
Fl	
	100·74

The specific gravity of this mica is 3·25.

Hornblende. This mineral is not so common as biotite. Mention was made by Adams, in his first description of the Dungannon occurrences, of the fact that two distinct varieties of hornblende, both green in colour, could often be distinguished in the same hand specimens, and this has been found to be true of outcrops in the southwestern and northeastern extensions of the band. The individuals are, as a rule, much larger than those of biotite, and present a nearer approach to perfection of crystallographic outline. The prismatic cleavages at angles of about 124° are often well seen. The first variety has a large axial angle, with strong pleochroism, in tints varying from pale yellow to deep green. Before the blowpipe it fuses with intumescence to a black glass, giving at the same time a strong soda flame. This variety probably contains a considerable quantity of soda, but approaches common hornblende in composition.

[1] An Examination of some Canadian Micas. Trans. Roy. Soc. of Canada, 2nd Ser. Vol. X, sec. 3, pp. 57-5[illegible] (1904).

The type specimen of the second variety occurs in a series of exposures about two miles to the east of the village of Bancroft, in Dungannon township. Dr. B. J. Harrington, in 1896, furnished an analysis, and discussed the chemical composition of this remarkable hornblende, and the associated titaniferous andradite. Accompanying this, Dr. Adams gave a brief petrographical description of the hornblende, although at the time no thorough examination of its optical properties was made.[1]

At the request of Dr. Adams, Mr. R. P. D. Graham, of the Geological Department of McGill University, undertook a detailed optical examination, the following being an extract from his paper, which has already appeared.[2]

"The hornblende is distributed throughout the rock in fairly large amount as small black individuals or aggregates with a high lustre, especially on the cleavages; but no fragments having crystal faces were found on the specimen examined. Except in very thin flakes, it is practically opaque.

Under the microscope in parallel light, thin sections appear quite fresh and greenish in colour, with a very strong pleochroism. Those rhomb-shaped sections, which are cut more or less perpendicular to the prism, and show the two sets of cleavage cracks intersecting at about 56°, are yellowish green for light vibrating along the shorter diagonal of the rhomb, and deep bluish green, or nearly opaque if the section is at all thick, for light vibrating parallel to the longer diagonal. Prismatic sections are also very strongly pleochroic, appearing deep bluish green to opaque when the light traversing them vibrates along the cleavage, and pale yellowish green for light vibrating perpendicular thereto. Between crossed nicols the latter have various angles of extinction with the cleavage cracks, the maximum value observed being about 30°.

Some fragments, however, while being distinctly pleochroic, exhibit this property in a comparatively slight degree, and these are further found to be almost isotropic between crossed nicols. When examined in convergent light, a dark cross, somewhat blurred and thickened at its centre is seen, and it was this unusual feature which first drew special attention to the mineral. The

[1] Am. Jour. Sc., Third Series, Vol XLVIII, 1894, p. 13; Am. Jour. Sc., Fourth Series, Vol. I, 1896, pp. 210-218; Can. Record Sc., Vol. VII, 1896-97, pp. 77 87

Trans. Roy. Soc. Can., Third Series, 1908-9, Vol. II, sect. iv, pp. 20-22

[2] Am. Jour. Sc., Fourth Series, Vol. XXVIII, 1909, pp. 540-543

cross does not separate into very definite hyperbolas on rotating the section, owing to its ill-defined character, but that the mineral is not truly uniaxial is evident from the pleochroism of these sections, and also from the unsymmetrical manner in which the brushes are coloured.

In the paper referred to above, it was stated that the axial angle is over 30°, and possibly as much as 45°, the optic axes lying in the plane of symmetry, with a strong dispersion in the sense $\rho > v$.

The optical determination of the mineral in the ordinary rock sections is a somewhat difficult matter, owing to the fact that even the thinnest slices, when cut normal to the acute bisectrix, have a very deep bluish green colour, causing the whole field to be dark, while the power of the objective under which it can be examined is also necessarily limited in such cases. In the present instance, small chips of the mineral were crushed very finely under oil and examined under a 1/12" oil immersion objective. The majority of the fragments were minute cleavage flakes, with a high extinction angle, the mean observed value being 22°, and they exhibit the strong pleochroism noted above for prismatic sections. The birefringence is low, compensation taking place when the quartz wedge is inserted across the prism. The dark brush which crosses the field on rotating the section (or the nicols) in convergent light is broadly fringed with red on one side and blue on the other, indicating a strong dispersion.

But there are always a few fragments lying on a plane which is approximately normal to the acute bisectrix, and when these are sufficiently thin they exhibit a fairly well defined optical figure. As had been previously noted, the central part of the interference figure, even when in the diagonal position, is not well illuminated, owing to the deep colour and the weak double refraction of the mineral. The quasi-uniaxial figure is coloured red in one pair of opposite quadrants, transverse to the cleavage cracks, and bluish green in the other, and it is usually difficult to decide as to which of these directions is the line joining the optic axes. If the axial plane lies in the plane of symmetry, as is usual in hornblende, then the angle for red is greater than that for blue, or $\rho > v$. But when exceedingly thin and less highly coloured chips are examined, it is found that the hyperbolas open out *across* and not along the plane of symmetry. They are coloured red on

their concave side, and although the brushes are thick and frayed, a certain amount of bluish green light gets through in the narrow space which separates them, and the same colour tints the rest of the figure. It was at first thought that this effect might be only an illusion, and due to the fact that more light is transmitted near the red portions of the figure than elsewhere, thus causing an apparent opening of the hyperbolas in this direction. But the phenomenon was observed in many cases so clearly as to admit of no doubt in the writer's mind that in hastingsite the axial plane, for green light at least, lies at right angles to the plane of symmetry of the mineral; the axial angle for red light is less, and there may even be a crossing of the optic axial plane for these colours, since the interference figure observed in yellow light approaches more nearly to the uniaxial cross, although it is very ill-defined owing to the poor illumination of the field. The birefringence is weak and negative. Although the pleochroism of sections cut in this direction is comparatively slight, it is in the same sense as that noted above for those parallel to the prism.

Considered with reference to the crystallographic axes, the pleochroism is like that usually met with in amphiboles; but since in the case of hastingsite the plane of the optic axes lies across the plane of symmetry instead of along it, we have $\mathbf{b} > \mathbf{c} > \mathbf{a}$, $\mathbf{b}$ and $\mathbf{c}$ being nearly equal.

It is impossible to make any accurate measurement of the optic axial angle, but it is evidently quite small. It was thought that it might be useful to make a rough estimate of its value by comparison with some other mineral of small angle, and biotite was selected for this purpose. A cleavage flake, in which the hyperbolas separated to about the same extent, so far as could be judged by the eye, as in the case of hastingsite, when examined under similar conditions, was found to have an axial angle, $2V = 17° 12'$; and allowing for the difference in refractive index between the two minerals, this would give for hastingsite, $2V = 16°$. From the nature of the method employed in arriving at this value, it can at the best be considered only as an extremely rough approximation; but it serves to indicate the probable order of the axial angle, which is much smaller than at first suggested.

The mean refractive index was determined by Schroeder van der Kolk's method, using thin cleavage fragments placed in the position of least absorption, i.e., for light vibrating across the

prism. The liquids employed were methylene iodide and naphthalene monobromide, which mix to form a clear solution. The refractive index of the resulting mixture, after adjusting as nearly as possible to that of the mineral, was determined in the usual manner, by means of a hand refractometer. The mean of several determinations gave 1.69 as the index of refraction of the mineral for light traversing it in this direction."

This hornblende was analyzed by Dr. Harrington with the following results:—

SiO_2	34·184
TiO_2	1·527
Al_2O_3	11·517
Fe_2O_3	12·621
FeO	21·979
MnO	·629
CaO	9·867
MgO	1·353
K_2O	2·286
Na_2O	3·290
H_2O	·348
	99·601
Specific gravity	3·433

The name hastingsite was suggested as a varietal name for this hornblende, thus connecting it with the region where it occurs.

Muscovite. The mineral has a pearly white, pale yellowish, or occasionally a pale lavender tint. Under the microscope the thin sections show no pleochroism, and only a very slight difference in absorption, but with very strong negative double refraction.

This mineral seems to occur in two definite and distinct forms. In the first place, it occurs in comparatively small individuals, somewhat similar in dimensions and habit to the biotite, which is the usual and more abundant mica. In this mode of development it is often intergrown with the biotite. As large individuals, together with nepheline and sodalite, it constitutes a pegmatitic phase of the nepheline syenite, in the first concession of Monteagle township, on the York river.

In the second place, muscovite occurs in much larger plates and aggregates, in more or less intimate association with corundum, in those types of the syenite which have consolidated from a magma supersaturated with alumina. It is, therefore, present in greater abundance, and more characteristic of these somewhat unusual types of the nepheline syenite, which, mainly by the almost complete failure of the ferromagnesian minerals, favoured the separation of the excess of alumina in the form of corundum. The mineral, under these conditions of association, has always been described and regarded as secondary, resulting from the alteration of the corundum. The supporters of such a view argued that every gradation in the process of this alteration may be seen, from those occurrences in which comparatively pure crystals of corundum are penetrated or coated with thin films or scales of the mica, to others in which the whole of the original corundum crystal has been replaced by muscovite. On the other hand, the peculiar conditions which attended and contributed to the replacement have never been satisfactorily explained. Both minerals are developed side by side in perfectly fresh and unaltered rocks, the surrounding constituent minerals having undergone little or no perceptible change. Moreover, it is well known that corundum is one of the most unalterable of substances when subjected to ordinary processes of atmospheric decay, this fact receiving the strongest support from the Ontario occurrences. The critical and extended studies of these Ontario deposits of corundum, both in the field and in thin sections under the microscope, is amply convincing that this apparent alteration is closely connected with some phases of pneumatolytic or vein action, which immediately preceded the complete solidification of the enclosing rock from the molten magma. The extreme phases of such alteration are best seen in the pegmatitic or coarser varieties of the syenite, although examples are not lacking in the more normal grained portions of these rocks. Indeed it seems to belong to the same class as that which gives rise to the corona or reaction rims which so frequently surround some of the earlier formed minerals in many plutonic rocks. (See Plates LIV, LV, LX, and LXII.)

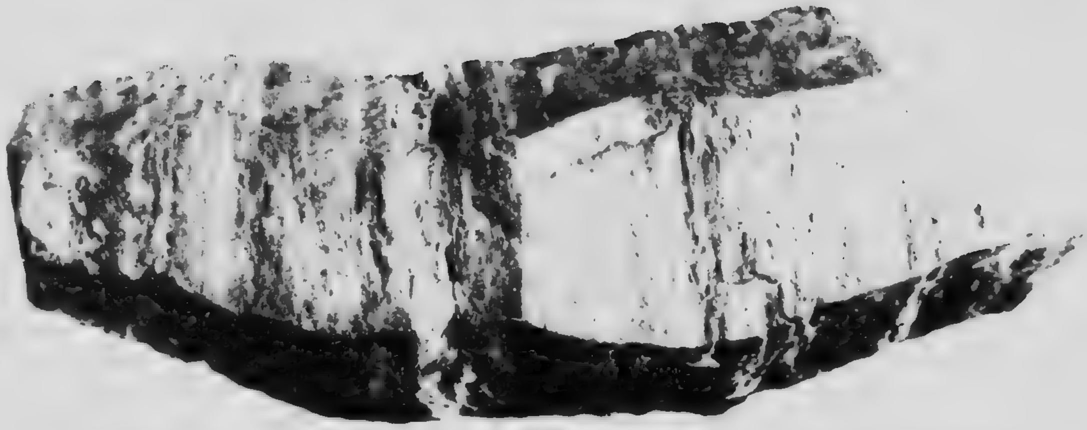
The alteration in the case of the Ontario corundum is always to muscovite, and this mineral may chemically be considered as made up of orthoclase, corundum, and water. Morozewicz has shown experimentally that a magma such as that which on cooling

CORUNDUM IN MUSCOVITE

(BLUE MOUNTAIN, METHUEN TOWNSHIP, ONTARIO

Corundum is often surrounded by a "Corona" or Mantle of Muscovite

PLATE LV.



Crystal of corundum (measures 7 x 2½ inches) showing muscovite developed along basal parting plane Craigmont, Raglan township, Ontario.

gives rise to a soda-syenite has the power to dissolve alumina, and on cooling to separate out any excess completely. The conditions laid down by what is known as Morozewicz's law (see page 320) are completely fulfilled by the corundum-bearing nepheline syenites of Ontario. In all magmas, those of acidic composition especially, water is believed to be present in considerable amount. As the corundum separated out the magma would tend to approach more nearly to the composition of a mass of fused feldspar, together with a certain amount of water. At this stage, and on account of some condition, or change of conditions, this residual magma attacked the corundum and more or less re-dissolved it, the hydrous feldspathic magma, together with the alumina from the dissolved corundum making muscovite, which crystallized around or replaced the corundum, according to the following formula:—

K_2O, Al_2O_3, $6SiO_2$ (orthoclase) $+ 2Al_2O_3$ (corundum) $+ 2H_2O = K_2O$, $2H_2O$, $3Al_2O_3$, $6SiO_2$ (muscovite).

This would likewise explain the marked prevalence of this alteration in the pegmatitic facies of the syenite, for it is in these residual differentiated portions of the magma that water plays such an important part in the process of crystallization.

Corundum.—The crystals, when normally developed, are usually six-sided prisms, which are sometimes terminated by a six-sided pyramid, and not infrequently by the basal plane. Many of the crystals, especially those occurring in the nepheline syenite, have a tolerably sharp and perfect outline, frequently showing a tapering to either extremity, thus producing the very characteristic barrel-shaped outline. The pyramidal and prismatic faces are very often more or less deeply striated or grooved horizontally. The basal planes or truncated ends of the crystals are frequently striated in three directions, forming equilateral triangles, corresponding with the less perfect rhombohedral partings or pseudo-cleavages. The crystals vary greatly in size, the largest noticed in the nepheline syenite being about eight inches in length by two inches in diameter. Such crystals are comparatively rare, the usual size being about two to three inches, and from that shading down into those of microscopic dimensions. Some of the larger crystals, as well as the very small ones, are usually inclined to have an irregular or imperfect outline. The corundum is in many instances somewhat brittle, breaking with

an uneven or conchoidal fracture, but when in large masses it is exceedingly tough. The lustre is in general vitreous, but in the translucent light green variety noticed in Brudenell township the lustre is somewhat pearly. The colour of the corundum in the nepheline syenite is, in general, of varying shades of blue to white. It is sometimes of a distinct rose-red colour. Many of the crystals, especially those present in the nepheline syenite exposures in the vicinity of York river, show an irregular or cloud-like arrangement of the colour material, shading off from deep azure blue through pale blue to colourless. Occasionally crystals exhibit a very decided and beautiful zonal arrangement. The hardness of the mineral is 9, or second only to that of the diamond. The specific gravity of the blue corundum from the nepheline syenite of Dungannon ranged from 3·93 to 4·01, with an average of 3·95.

A microscopical examination of the thin sections of this rock show that, in addition to the larger and more perfect crystals which are visible to the naked eye, there are innumerable small, usually exceedingly irregular individuals distributed through the rock, which would add greatly to the richness of the product derived from concentration.

Corundum under the microscope has a high index of refraction, but a low double retraction, and in good thin sections the interference colours do not exceed red of the first order. Such sections are, however, difficult to obtain on account of the relatively much greater hardness of corundum than the surrounding minerals. These latter may be thin enough, while the corundum grains, as may be seen in sections from which the cover glass has been removed, are in considerable relief, the result of their resistance to the grinding operations. As a consequence, therefore, the corundum is given a higher double refraction than it actually possesses. Most thin sections, therefore, of this mineral, show very brilliant chromatic polarization between crossed nicols. The pronounced relief, the dark borders of total reflection, the rough surfaces, and the parting planes or pseudo-cleavages are very strongly marked with negative double refraction. The following localities show corundum in nepheline syenite, most of which are of economic importance.—Lot 12, concessions XI and XII, lot 18, concession XI, lot 12, concessions XIV and XV, lots 6 and 7, concession XV, lots 6 and 7, concession XVI, Dun-

gannon township. Lot 4, concession I, Monteagle. Lots 2 and 3, concession II, Monteagle. Lot 34, concession V, lot 25, concession VI, and lot 32, concession VII of Brudenell township. An analysis of the blue corundum occurring in the syenite on lot 12, concession XV of Dungannon, is given on p. 323, and an analysis of that occurring at Craigmont on p. 329.

Calcite. This mineral is almost invariably present, and is especially abundant in those exposures which are in immediate contact with crystalline limestone. Its unexpected presence in such a rock has already been fully explained, and the interpretation that this mineral is distinctly foreign to the magma, and derived from the neighbouring limestones, is in direct agreement with all the phenomena observed. Its mode of occurrence is entirely different from that of a secondary constituent, being found in comparatively large, well defined, usually rounded grains, sometimes completely enclosed by the other constituents, or in other cases lying between them. (See Plate LI). The line of separation is quite sharp and distinct, with no hint of decomposition in any of the surrounding minerals. The individual grains show the usual perfect rhombohedral cleavages, often with well marked twinning lamellæ. Comparatively large individuals occur in the pegmatitic phases, as noticed in the exposures east of the bridge over the York river, in Dungannon township. (See also Plate LII).

Garnet. This mineral is of common occurrence, and is occasionally so abundant, especially at certain exposures near the York river, in the northern part of Dungannon, as to characterize the rock. In the hand specimen it exhibits a dark reddish brown colour. In thin sections it is, of course, much paler in tint, assuming a deep brownish tint, fading to yellowish towards the interior of the larger grains. It shows the usual high index of refraction and consequent very pronounced relief. It is quite isotropic. The individuals, and especially the larger grains, usually possess a very jagged outline, with irregular arms and intricate indentations, with very abundant inclusions of most if not all of the other constituent minerals. In some instances it exhibits well developed crystallographic boundaries. It is especially abundant in those varieties of the syenite which contain hornblende as the ferromagnesian mineral, and is for the most part developed in immediate association with this mineral. It

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

1.0 4.5 2.8 2.5 5.0 3.2 2.2 5.6 3.6 4.0 2.0 1.1 1.8 1.25 1.4 1.6

APPLIED IMAGE Inc

resembles a garnet found in small amount in the nepheline syenite of the Corporation quarry at Montreal, and also the melanite in the nepheline syenite of Alno.[1]

Chemical analysis by Dr. B. J. Harrington[2] afforded the following results, showing the garnet to be a titaniferous andradite:—

SiO_2	36·604
TiO_2	1·078
Al_2O_3	9·771
Fe_2O_3	15·996
FeO	3·852
MnO	1·301
CaO	29·306
MgO	1·384
Loss on ignition	·285
	99·577
Specific gravity at 16° C.	3·739.

Zircon.—This mineral is quite commonly seen in thin sections under the microscope, but it is usually a comparatively rare accessory constituent. The microscopic representatives are rather short prismatic forms, and as a rule somewhat rounded. The index of refraction and the double refraction are very strong, giving characteristic strong relief, and brilliant red and green interference colours, between crossed nicols. In some of the coarser phases of the rock, noticeably at the York river in Dungannon, and at Craigmont in Raglan, crystals are not uncommon which would measure from a quarter to half an inch in length. One short, stout crystal, at present in the museum of the Geological Survey, measures an inch in length by three-quarters of an inch across. It is in almost perfect condition, with the various crystal planes and angles quite sharp and definite. Some of these crystals were sent by Dr. Adams to the Mineralogical Laboratory of the Sheffield Scientific School, at New Haven, for crystallographic investigation. Mr. J. H. Pratt, to whom they were entrusted, gives the full details of this examination, from which the following is

[1] Geol. Fören. i. Stockholm Förh. 1895, p. 144.

[2] Can. Rec. Sc. Vol. vi, 1894-95, pp. 480-481, also Vol. vii, 1896-97, pp. 87-88.

taken[1]: "The crystals occur embedded in the usual manner in the rock, from which they can readily be separated in an almost perfect condition. They show two quite different habits, one, in which by the development of two opposite pairs of the pyramidal faces, together with a pair of the prisms of the second order, the crystal becomes columnar in this direction, and mimics a hexagonal prism of the second order terminated by rhombohedral faces. In the second habit the pyramidal faces are strongly developed, while the prism faces are short or lacking altogether." Both these habits are represented by good specimens in the Geological Survey museum. The comparatively large individual already mentioned belongs to the second habit.

Sphene (*Titanite*).—This mineral is also sometimes represented, although by no means abundant, and, so far as observed, in microscopic crystals only. It is often in characteristic wedge-shaped though somewhat rounded forms, but also occurs in irregular grains. It is more abundant in the hornblendic varieties, where it is often quite an important accessory constituent. The index of refraction is high, and as a consequence the individuals show very pronounced marginal reflection and rough surface. The double refraction is quite strong in some sections. It sometimes has a comparatively strong yellowish brown colour, with quite a perceptible pleochroism.

Tourmaline.—This mineral was only noticed occasionally, and in small amount. It occurs in characteristic crystals, which are black in colour. It was noticed in the nepheline syenite on lot 12, concession XV of Dungannon, and lot 4, concession I of Monteagle.

Spinel (*Automolite*).—A dark green spinel, evidently closely allied if not identical with automolite, has only occasionally been noticed in connexion with the nepheline syenite, although it is more abundant in the red alkali syenite. It has, however, been distinguished in thin sections of the nepheline, a rich variety occurring on lot 33, concession VII of Brudenell, where it occurs in irregular dark green isotropic grains.

Eucolite.—A mineral with the characters of eucolite occurs rather abundantly in the hornblendic variety of the nepheline syenite at Egan chute, on the York river, as well as at another

[1] Amer. Jour. Sc., Vol. xlviii., 1894, p. 215.

locality a little lower down the same stream. It occurs with a yellow colour, usually with incomplete crystallographic boundaries. It is intimately associated with hornblende and garnet, frequently enclosed in the former, and with an appearance altogether suggesting th latter mineral. It has, however, quite a distinct though apparently low double refraction, but a high index of refraction, with decided relief, a rough surface, and parallel extinction. It is distinguished from the garnet by a decided difference in colour, the garnet being brownish or reddish brown in thin sections, while the eucolite is pale yellowish. Treated with the heavy solution, eucolite falls with the hornblende and garnet, and can only be separated with the greatest difficulty from these minerals. By magnetic separation several times repeated fairly pure material is obtained, but hardly pure enough for purposes of chemical analysis. It is likely that further and more careful search in this region would show larger and more abundant individuals of this mineral.

Molybdenite.—This mineral is occasionally represented, and occurs usually in small plates and scales, and occasionally in crystals. It presents no unusual features worthy of description in the present instance. Two localities where it may be found without any great difficulty are lots 25, concessions XIII and XIV of Dungannon. Large specimens may also be obtained from certain of the openings in the corundum syenite at Craigmont.

Apatite.—This mineral is a very common constituent of the nepheline syenite, but it is usually present as a very subordinate accessory constituent, and in very small, often microscopic crystals. In such cases it rarely possesses sharp crystallographic outline, but occurs as comparatively short stout prisms, often doubly terminated, but these crystal planes are either disguised or obliterated by rounding, the result doubtless of magmatic resorption. In some localities in Dungannon, especially on lot 25 of concession XIV, and in association with the iron on lot 30, concession XIII, comparatively large crystals of apatite may be obtained, while in the northwest corner of Faraday well defined prisms, terminated at one end with the planes of two pyramids, have been noticed. (See Plates LVI and LVII.)

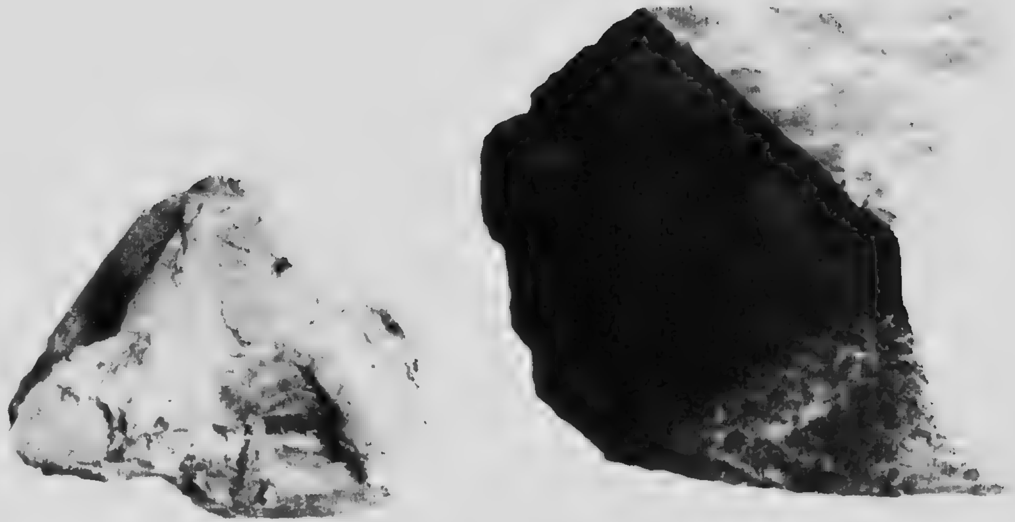
Magnetite.—This mineral has a very general distribution throughout the whole mass of the nepheline syenite, although its complete and unexpected absence from occasional outcrops, representing even the more basic phases of the rock, is noteworthy. It is usually present, however, and certainly one of the more im-

PLATE LVI.

Curved crystal of apatite in nepheline syenite, with calcite, lot 25, concession XIV, Dungannon township.

Crystals of apatite from nepheline syenite, lot 30, concession XV, Faraday township

PLATE LVIII



Crystals of magnetite from nepheline syenite (lot 30, concession XV, Faraday township).
Large crystal weighs $7\frac{1}{4}$ lbs.

portant of the accessory constituents. Individuals in thin sections under the microscope often show fairly good crystalline form, but the grains are usually somewhat rounded and irregular in outline. The mineral is not so conspicuous or abundant as in the more feldspathic variety, especially the red syenite. In many places the magnetite differentiates out from the rest of the rock, and forms large and important masses of this mineral, much of which is free from any other admixture. Attempts have sometimes been made to work some of these masses in the hope that they would ultimately become producing mines. At one locality, on lot 30, concession XIII of Dungannon, considerable development work, consisting chiefly of stripping and blasting, has revealed the presence of considerable bodies of very pure magnetite, which, however, judging from analogous occurrences accompanying the red syenite, and which have been analyzed, would in all probability contain titanium. The mineral here has a very perfect octahedral parting. In certain localities in Dungannon, and especially in the northwest corner of Faraday, perfect octahedrons of magnetite can be occasionally secured, weighing several pounds. An analysis of the magnetite from the corundum syenite pegmatite of Craigmont is given on page 329. (See Plate LVIII).

Pyrite, Pyrrhotite, and Chalcopyrite.—All three of these sulphides have been noticed as constituents of the nepheline syenite. The pyrite is the most common. Under the microscope it is occasionally present in small well defined cubes, but usually it occurs in rounded or irregular grains. The reddish brown stains so frequent in some exposures of the rock are due to the presence of this mineral in a more or less oxidized condition.

Graphite.—This mineral is not, so far as observed, a frequent or abundant constituent, but it has been noticed in the coarse phase of the nepheline syenite exposed to the east of the York river, in Dungannon township. It occurs very pure, in small rounded shot-like forms, consisting of minute scales of this mineral arranged in a radiating or plumose manner. In certain portions of the rock at this locality graphite in this form is quite abundantly distributed. It has been noticed as an important and characteristic mineral in a certain variety of the nepheline of Sivamalai, in India, described by Holland, where it constitutes 0·58 per cent of considerable masses of the rock[1].

[1] Mem. Geol. Surv. Ind. Vol. xxx part 3, pp. 174 and 175.

Holland explains its presence in this rock as due to its crystallization from fusion, and regards it as a primary constituent and older than the feldspar. This conclusion is satisfactory also in the case of the York river nepheline syenite.

DESCRIPTION OF THE VARIOUS OCCURRENCES OF THE NEPHELINE AND ALKALI SYENITE.

For purposes of description it will be most convenient to group the several occurrences by townships, as follows:—

1. The alkali syenites of the township of Lutterworth.
2. The nepheline and associated alkali syenites of the township of Monmouth.
3. The nepheline and associated alkali syenites of the township of Glamorgan.
4. The nepheline and associated alkali syenites of the townships of Harcourt, Cardiff, and Wollaston.
5. The nepheline and associated alkali syenites of the township of Methuen.
6. The nepheline and associated alkali syenites of the townships of Faraday, Dungannon, Carlow, Monteagle, Raglan, and Brudenell.

The information concerning groups 2 to 5 inclusive is derived from the investigations of F. D. Adams, while that concerning group 6 is due chiefly to A. E. Barlow.

1. ALKALI SYENITES OF THE TOWNSHIP OF LUTTERWORTH.

This corundum-bearing syenite, which, however, lies just outside the limits of the area embraced by the present report, was discovered on lot 12, concession IV in this township, by Mr. Tett, when acting as assistant to W. A. Johnson, of the Geological Survey of Canada, in the summer of 1905. This rock is said to occupy an area from thirty to forty acres in extent, and to cut the gneissic granite of the district. Much of the rock contains over ten per cent of corundum.[1]

2. NEPHELINE AND ALKALI SYENITES OF THE TOWNSHIP OF MONMOUTH.

The nepheline syenites of this township may be considered as distributed in three groups.

[1] Geological Survey of Canada, Summary Report, 1905, p. 93.

The first of these consists of a remarkable belt of nepheline syenite, which occurs as a border around a body of pegmatitic granite situated near the centre of the township, and stretching in a direction about north 30° east, from concession VII to concession XIV, a distance of about 6 miles. The granite mass has a maximum width of a little over one mile. The border of nepheline syenite about the mass varies from one-eighth to half a mile in width, and can be continuously traced from lot 29, concession XIV, where it is well exposed along the Haliburton road, down the westerly border of the granite mass, along its southern border, and up the east side as far as lot 27 concession XIV, a distance of about 10 miles. To the northeast, both the granite and the nepheline syenite about it are lost beneath a drift flat, through which, on concession XIII, some bosses of the pegmatite protrude. The only point along this border in which the continuity of the nepheline syenite is not a matter of certainty is at the extremely southerly point of the occurrence on concession VII. Here the country is drift-covered, but numerous blocks of the syenite are found at this point, while it is seen exposed on the Monck road, which runs along the rear of this concession, both to the northeast and northwest, and, furthermore, the strike of the foliation of the syenite itself, and of the enclosing limestones, which always conform to it, indicates a continuance of the band of syenite around the southern end of the pegmatite, as shown on the Bancroft sheet.

Fine transverse sections from the limestones on either side, through the nepheline syenite border to the central mass of granite, can be seen on the several roads which cross the occurrence, as shown on the map.

The rock, which has been referred to as pegmatite or granite, is pink or red in colour, and is usually of medium grain. It has, in many places, that irregular and often rapid variation in size of grain which is seen in the pegmatites. At the northeastern end of the mass, on lot 29, concession XIII, it has a distinctly foliated structure. Farther south the foliation becomes less distinct, although the rock still retains a streaked appearance. The rock is never rich in quartz, although in the northeastern part of the mass, and as far south as concession XI, this mineral is present in considerable amount; further to the southeast the quartz decreases in quantity and the rock passes into a syenite.

The rock as developed on lot 26, concession XII of Monmouth, the middle of the mass, is a medium-grained granite-gneiss, red in colour, and with a rude foliation. The quartz is light grey and glassy. The feldspar is red on a fresh surface, showing good cleavage and high lustre, and weathering to a pale red or pink. The dark constituent is in small amount, and is not determinable macroscopically.

Under the microscope the rock is seen to be composed of albite, microcline, orthoclase, microperthite, quartz, hornblende, biotite, sphene, apatite, and magnetite.

The structure is hypidiomorphic. There are evidences of cataclastic action in the strain shadows, and the incipient granulation of some of the quartz and feldspar individuals. The feldspar is fresh, but is stained along the borders by iron oxide, to which to some extent the colour of the rock is due. It occurs in large individuals, with broad interstitial areas of smaller ones. Albite is irregular in form, and is well-twinned according to the albite law, with occasionally additional pericline twinning. The larger individuals interlock with those of the microperthite. The microperthite is present in considerable amount, and is seemingly an intergrowth of albite and microcline. The microcline, with the usual cross-hatched structure, as well as the orthoclase, are subordinate in amount to the albite. From a separation by means of the Thoulet solution, it was found that the amount of albite and microperthite together was almost double the amount of orthoclase and microcline. Quartz is present in amount equal to the potash feldspars. It is clear, but holds strings of black opaque inclusions.

The ferromagnesian constituents occur in aggregates of individuals of rather frayed or ragged outline, very few approaching an idiomorphic form. The hornblende is of two varieties, a green and blue. The green is evidently common hornblende, having a pleochroism in green and yellow tints, and an extinction of 20°. It is much altered to a yellowish chlorite. The blue is intergrown with the green variety, and has absorption colours ranging from deep lavender blue to light green. Biotite is present in insignificant amount. Sphene, light yellow in colour, and in part of wedge-shaped form, occurs with the magnetite. The zircon and apatite are represented by a few rudely idiomorphic grains.

The syenitic phase of the rock above mentioned is well seen on lot 15, concession VIII of Monmouth, which is near the southeastern end of the mass. It is red in colour, and composed almost exclusively of feldspar, which is for the most part microperthite. The iron-magnesia constituents occur in occasional dashes, with rudely parallel arrangement. It differs from the granite in that no hornblende is present, and no quartz is visible in the sections; while in addition to the small amount of biotite which the rock contains, a little muscovite and calcite are present. The latter may be secondary. The soda feldspar preponderates over the potash feldspar, as shown by the analysis given below.

An analysis of this rock was made by Prof. Norton Evans, with the following result:—

SiO_2	64·15	per cent.
Al_2O_3	19·04	"
Fe_2O_3	1·02	"
FeO	·93	"
MnO	·16	"
CaO	1·37	"
MgO	·37	"
K_2O	7·10	"
Na_2O	5·37	"
P_2O_5	·10	"
CO_2	·70	"
H_2O	·27	"
	100·58	

If the norm of this rock be calculated it will be found to be as follows. The calcite is considered to be secondary and is therefore omitted:—

Quartz	1·86	per cent.
Orthoclase	42·26	"
Albite	45·59	"
Anorthite	5·84	"
Corundum	·30	"
Hypersthene	2·09	"
Magnetite	1·39	"
Apatite	·34	"

The position of the rock in the quantitative classification is accordingly as follows:

Class I	Persalane.
Order 5	Canadare.
Rang 1	Nordmarkose.
Sub-rang 3	Phlegrose.

It is a matter of question whether the calcite should be considered as an alteration product, or as representing little inclusions of the surrounding limestone, as in the case of the nepheline syenites described below. If, as above, all the lime be considered as belonging to the magma, the rock lies near the line between Phlegrose and Pulaskose.

The mode of the rock—that is to say, its actual mineralogical composition—is found on calculation to be as follows:

Quartz		4·20	per cent.
Orthoclase		37·25	"
Albite	45·59	47·26	"
Anorthite	1·67		
Muscovite		4·78	"
Biotite		3·93	"
Magnetite		1·39	"
Apatite		·27	"
Calcite		1·60	"
		100·68	

This granite-syenite rock fades away into the nepheline syenite on either side. This takes place by the disappearance of the quartz, if any be present, with the concomitant increase of the soda feldspar at the expense of the potash feldspars, and the increase of the proportion of iron-magnesia constituents present. A little nepheline also appears in most cases. An albitic phase of the nepheline syenite thus results.

The transition of the granite to the nepheline syenite through this albitic phase is excellently seen at the locality referred to above namely, lot 26, concession XII of Monmouth. The transitional albitic rock is rather coarse in grain and dark in colour, with a faint reddish tinge, showing on the weathered surface a little nepheline, and in one or two places small crystals of corundum. There are

also, as is often the case in this variety, rather large grains of magnetite scattered through the rock. The rock has a distinct foliation, due chiefly to the approximately parallel arrangement of the biotite, of which a large amount is present.

Under the microscope the rock is seen to consist of albite, orthoclase, microcline, and a little microperthite, with nepheline, biotite, and calcite. As very subordinate constituents, magnetite and apatite are present. A separation by means of Thoulet's solution shows that there is about eighteen times as much albite as potash feldspar present. The nepheline is sparingly represented, and is almost wholly altered to a turbid product of composite character. This varies in colour from brown to a light yellow, and, under a high power, is seen to have a radiating fibrous or lamellar structure. The index of refraction is low, while the interference colours vary from orange and yellow in the fibrous to orange and purple in the lamellar portions.

The biotite is in lath-shaped individuals of a brown colour, with strong absorption, $\mathfrak{a}$ dark brown and $\mathfrak{c}$ light brownish yellow. The calcite is present in considerable amount and in the form of large grains, each composed of a single individual, included in the nepheline, or lying between the other constituents of the rock. A few crystals of corundum were found by carefully examining the exposed surface of the rock. The amount present, however, is small, and the mineral does not occur in the slides which have been prepared.

The transition between a syenitic phase of the granite mass and the nepheline syenite is well seen at the southern end of lot 15, concession VIII of Monmouth. The nepheline syenite here has a *schlieren* structure, caused by the variation in the relative amount of the constituent minerals in different streaks. Some of these *schlieren* consist of the red syenite, and others are intermediate in character between the red syenite and the nepheline syenite. There is thus represented in these *schlieren* a complete transition from the red syenite to the normal white or grey nepheline syenite. Under the microscope this intermediate rock is seen to be quite similar in character to that above described from lot 26, concession XII of Monmouth. The albite and potash feldspars are present in the ratio of about 19 to 4, as shown by a separation with the heavy solution. The albite has a specific gravity of slightly over 2·62. Nepheline is present in small

amount. The biotite is less abundant than in the rock from lot 26, concession XII, but occurs in lath-shaped forms. **a** = deep greenish brown and **c** = straw yellow. Calcite is present, occurring in the same manner as before, and the same accessory constituents, together with a little pyrite and zircon, are seen.

The nepheline syenite which forms the border of the mass has a distinctly foliated structure, and is coarse in grain. It is white to dark grey in colour, according to the proportion of the iron-magnesia constituents which it contains. In a few places, as, for instance, on lot 23, concession XI, it is pale pinkish, owing to the presence of a pink gieseckite-like alteration product of the nepheline. The rock is by no means uniform in composition, but usually possesses a rudely banded or *schlieren* structure, which conforms to the direction of the foliation, the different *schlieren* being marked by a variation in the relative percentage of the several minerals present. Thus, in some *schlieren* the rock will be rich in nepheline, while in the adjacent ones the nepheline will almost or entirely disappear; again, there may be a variation in the relative proportion of the iron-magnesia constituents, which will give rise to a change in character. As a place where the rock is locally very rich in nepheline, lot 24, concession XII may be cited, the nepheline rock here in some places containing much magnetite in large grains scattered through it. These bands are usually of considerable dimensions, being several feet to many yards in width, and of course are not sharply defined, but fade away into one another, although rather abruptly. Occasionally the grain of the rock will suddenly become much coarser, the rock passing into a pegmatitic facies, this being most common in those places where nepheline is abundant.

The nepheline syenite from five different localities on the band, representative of the chief types occurring in it, was studied microscopically. These localities were the following:—Lot 16, concession IX, lot 24, concession XII, lot 27, concession XII, lot 23, concession XI, and lot 18, concession VII. They will be considered in this order.

Nepheline syenite, Monmouth, lot 16, concession IX.—This represents the albite-rich phase of the rock, being very rich in albite and poor in nepheline. It is taken from the east side of the road, between McCues lake and Hotspur, about one-third of the way south of the northern limit of the band. It is coarse in grain, and possesses a distinct foliation.

Under the microscope it is seen to have a hypidiomorphic structure, and to consist of the following minerals:—Albite, microcline, microperthite, nepheline, lepidomelane, magnetite, and calcite. In some few *schlieren* a dark green hornblende (probably hastingsite) replaces a portion of the biotite. Albite and lepidomelane are the chief constituents. The albite is well twinned, and must be a variety approaching the pure soda molecule, as it has a specific gravity of 2·618, and shows a maximum extinction against the line of the twinning lamellæ of 15°. In a single slide a few grains having an extinction as high as 20° were observed, showing that a plagioclase somewhat more basic than albite is also occasionally present in very small amount. The microcline presents its usual characters, and is frequently intergrown with albite, forming microperthite. The nepheline is in the form of large individuals similar in shape and dimensions to those of the albite. Smaller individuals of it are sometimes seen to be included in the albite, while in other cases it includes individuals of albite. It is very fresh and free from alteration products. The lepidomelane is the same dark brown, highly pleochroic variety of biotite already mentioned as occurring in the transitional rock lying between the granite and the nepheline syenite and has the form of short laths. A light coloured yellow mica is also present in smaller amount. The calcite occurs in large, single individuals, often of a rounded form, sometimes enclosed in the feldspars, nepheline, or lepidomelane, but usually lying between the other constituents. The enclosing minerals are quite fresh, while the calcite shows no signs of secondary origin. The magnetite is in large, sub-angular, or more or less rounded grains. There seems to be no definite order of succession in the crystallization, seeing that the various minerals enclose and penetrate one another. The lepidomelane, however, has a much better form than the other constituents, and would thus seem to have crystallized earlier.

An analysis of the biotite-bearing variety of this nepheline syenite was made by M. F. Connor, B.A.Sc., and gave the following results:—

SiO_2	51·58	per cent.
TiO_2	·35	"
Al_2O_3	19·40	"
Fe_2O_3	4·26	"
FeO	5·25	"
MnO	·20	"
CaO	3·64	"
MgO	·49	"
K_2O	4·23	"
Na_2O	7·49	"
P_2O_5	·15	"
CO_2	1·53	"
H_2O	1·02	"
	99·59	

The norm of the rock is as follows:—

Orthoclase	25·02
Albite	34·84
Anorthite	6·67
Nepheline	15·50
Diopside	·90
Olivine	5·05
Ilmenite	·73
Magnetite	6·15
Apatite	·34
Calcite	3·45
	98·65
Water	1·02
	99·67

The rock has thus the following position in the quantitative classification:—

Class II.	Dosalane.
Order 6.	Norgare.
Rang 2.	Essexase.
Sub-rang 4.	Essexose.

If the calcite be regarded as representing inclusions (and reasons will be given for thus considering it later on) the rock will lie just on the line between Essexose and Laurdalose.

The calculation of the mode of the rock, that is to say, the percentage proportion of the minerals actually present in it, cannot be made with absolute accuracy, since the precise composition of both micas present is not known. If, however, the micas be taken to have the same average composition as the lepidomelane from the nepheline syenite of Litchfield, Me.,[1] except that one per cent of alumina replaces an equivalent amount of ferric oxide, as is frequently the case in these minerals, the mode will be as follows:-

Orthoclase.		4·45	per cent.
Albite.	50·83	52·08	"
Anorthite.	1·25		
Nepheline		8·05	"
Biotite.		29·61	"
Iron ore.		·73	"
Apatite.		·34	"
Calcite.		3·45	"
Water.		1·02	"
		99·73	"

This gives a plagioclase of the albite series having a composition $Ab_{10\cdot8}An_1$ which is the proper composition as shown by the Thoulet separation. The composition assumed for the nepheline is that of the nepheline of the Dungannon nepheline syenite, the analysis of which is given on page 236. This arrangement of results leaves an excess of 1·25 per cent of lime and a deficit of 1·40 per cent of ferric oxide.

An analysis of the dark brown or black mica present in the rock is given on page 243, in that part of the report dealing with the minerals found in the nepheline syenites.

[1]Bull. 168, U.S. Geol. Survey, p. 21.

Nepheline syenite, Monmouth, lot 24, concession XII.—This locality is $2\frac{1}{2}$ miles northeast of the point from which the rock just described was obtained, and is situated on the same side of the granite mass. It belongs to the same albite facies of the rock, and is so similar to that from lot 16, concession IX, that no special description is required. Inclusions of both nepheline and albite were observed in the biotite of this rock. A few crystals of corundum were found weathered out from the surface at one place.

The nepheline syenite as developed on the east side of the granite opposite to the last occurrence, namely on lot 27, concession XII, is also identical in character, and merits no special description. It is, however, rather finer in grain and somewhat richer in biotite.

Nepheline syenite, Monmouth, lot 23, concession XI. The granite on lot 24 of this concession is succeeded at the river, on the line of lot 23, by a development of the albite facies of the nepheline syenite like those above described. On crossing the river this begins to snow nepheline, and develops into a typical nepheline syenite, which is seen in great exposures along the road which here crosses the width of the band, as far as lot 20, where it ends against the great body of crystalline limestone which bounds it on the west. It has the usual *schlieren* structure and a parallel arrangement of the constituents, streaks richer and poorer in nepheline alternating with one another, but nepheline often makes up from one-third to one-half of the rock, and sometimes is present in much greater proportion. It is usually coarse in grain, but occasionally the constituent grains become very large, reaching an inch or more in diameter.

Under the microscope the rock is seen to be composed of the same constituents as that last described, the following minerals being present:—Albite, microcline, some untwinned feldspar (probably orthoclase), microperthite, nepheline, lepidomelane, magnetite, and calcite. A few little individuals of zircon are sometimes noticed. Albite and nepheline make up the mass of the rock, the other minerals being quite subordinate in amount. A striking feature of much of this rock, however, is the alteration to which most of the nepheline has been subjected. On the fresh fracture this altered nepheline has a pink tinge, and under the microscope it is seen to have been converted into a turbid mat of alteration products. Pink alteration products,

deeper in colour but of very similar character, have been observed in the nepheline syenite of the township of Methuen, and other parts of this area. The alteration commences along cracks and cleavage planes, and goes forward until the whole individual is completely altered. The alteration product is of composite character. It contains a mineral with high double refraction and rather high index of refraction, and possessing a somewhat fibrous character which is unaffected by acid. This is probably muscovite. Associated with this in the aggregate are other minerals, which are probably kaolin and cancrinite. An analysis of the closely similar material from the township of Methuen shows that it has the same chemical composition as the aggregate known as gieseckite (see p. 296), which is a common alteration product of nepheline in other parts of the world.

Nepheline syenite, lot 18, concession VII.—This locality is near the extreme southerly end of the nepheline syenite band, the specimens being collected on the south side of the Monck road where it crosses this lot. The rock is rather coarse in grain with a rude foliated structure, and is dark in colour, being rich in iron-magnesia constituents. Little red specks can be seen dotting the fresh surface of fracture, and consisting of the altered nepheline. This mineral is not very abundant in the rock as a whole, but occurs in large masses in certain coarser grained *schlieren*, where it is often associated with zircon crystals. Under the microscope the rock is seen to be composed of the following minerals:—Albite, microcline, microperthite, nepheline, hastingsite, biotite, calcite, with a little accessory apatite, and an occasional grain of pyrite.

The feldspars have the same characters as those occurring at the other localities on this band. The microperthite, however, is relatively abundant, being present, as shown by a Thoulet separation, in about the proportion of 3 to 4 as compared with the albite. The albite has a specific gravity of about 2·62, most of it being slightly lighter than this and some slightly heavier, showing that it represents the nearly pure albite molecule. The nepheline, which is present in considerable amount, is for the most part altered to an aggregate similar to that described in the occurrence on lot 23, concession XI. The chief difference between this rock and those from the other localities is the replacement of the mica by hornblende. The rock still contains a little biotite, but

the hornblende preponderates very largely, making one of the chief constituents of the rock. It is a deep green variety, which is closely allied to, if not identical with the variety hastingsite, which has been described from the nepheline syenite of the township of Dungannon. It occurs in hypidiomorphic forms which occasionally show a good hexagonal outline on the basal sections, and possess strong pleochroism and a strong dispersion of the bisectrices. **c** and **b** are deep green. **a** is light greenish yellow. The absorption is **c** = **b** > **a** and the extinction angle is 30°. The calcite is not abundant and the thin sections contain no iron ore under the microscope.

In this body of nepheline and alkali syenite, corundum, which is so important as a constituent of these rocks in many places elsewhere in the area covered by this report, has nowhere been found as yet in workable amount. Its presence, however, was detected by Dr. Barlow in the albitic phase of the nepheline syenite bordering the granite on the west side of lot 26, concession XII of Monmouth, and by Prof. Miller on lot 15, concession VIII, and lot 28, concession XIII, and also at a point a little west of Hotspur post-office, where the road running to the north leaves the Monck road.

The second group of occurrences of nepheline syenite in the township of Monmouth consists of a lenticular shaped mass occupying portions of lots 9, 10, 11, and 12, concessions VII and VIII, together with several dikes of the same rock, cutting the limestones about a mile further south on concession VI.

The nepheline syenite constituting the first mentioned mass breaks through the crystalline limestone, of which it holds many inclusions. These included masses of the limestone are coarsely crystalline and have various silicates developed in them. The constituent minerals of the nepheline syenite have the appearance of growing into these masses. It might be supposed that the limestone was in course of solution by the magma, but there is no sign of an increase of lime-bearing silicates in their vicinity, for while in some places the nepheline syenite near the contact is rich in hastingsite, elsewhere about the border of the mass this and the other dark minerals which hold the lime are absent. The lime-bearing mineral scapolite in this occurrence is comparatively rare, and this apparent replacement of the limestone by a nepheline syenite which itself is poor in lime is a phenomenon

seen in all parts of the district, and will be referred to again in the general remarks on the nepheline syenites of the whole area. (See p. 332)

On the weathered surface of the syenite the limestone fragments, which are thickly scattered through the rock in many places, are dissolved out, leaving little pits and cavities, into which the individuals of the nepheline and other constituents of the rock project, often with rude crystallographic forms.

The nepheline syenite body has a marked foliation or gneissic structure, and is irregular in composition, consisting of a series of thick bands or *schlieren* running parallel to one another and to the strike of the surrounding limestones. Some of these *schlieren* are very highly feldspathic and hold but little nepheline. Much of the rock, however, is rich in nepheline, while in some of it nepheline replaces the feldspar almost entirely. Bands as much as six feet in width can be found which consist almost exclusively of nepheline, with some hornblende. Usually those portions which are rich in nepheline contain also much hornblende, often associated with red garnet in subordinate amount. Elsewhere they consist of nepheline and albite. In the latter variety small individuals of white mica sometimes occur which exactly resemble the crystals of this mineral which are formed by the replacement of corundum in other parts of the area. The highly feldspathic type which resembles those already described does not require further mention, but three typical varieties in which nepheline is more abundant have been selected for special study.

Nepheline syenite, township of Monmouth, lot 11, *concession VIII.*—(First variety). This represents a facies rich in iron-magnesia constituents. It is coarse in grain and dark in colour, and possesses a distinct gneissic structure.

Under the microscope it is seen to consist of nepheline albite, hornblende, and calcite, with a small amount of apatite as an accessory constituent. These minerals, with the exception of the apatite, are all in large individuals, and like most of the nepheline syenites of this area, have a distinctive structure which approaches the allotriomorphic. None of the minerals have a good crystalline form, but all have a tendency to occur with more or less rounded outlines and to come against one another in curved lines. Inclusions of one mineral in

another are common, no very definite order of succession is observable in the crystallization. In these respects the structure approaches the mosaic character characteristic of the metamorphic rocks in which complete recrystallization has taken place.

The nepheline is usually considerably altered to a very fine-grained turbid aggregate resembling kaolin, although in places it is quite fresh, and shows its usual optical properties. It frequently holds rounded inclusions of albite and of calcite. The albite is well twinned and possesses the usual characters. The hornblende, if not hastingsite, is a variety closely resembling it. It is deep green in colour, looks black on the fractured surface of the rock, and is the most abundant constituent. Although the rock is so basic, it contains no iron ore, which is elsewhere common as an accessory constituent in such rocks. The calcite, as usual, occurs as rounded inclusions in the albite, nepheline, or hornblende, or filling spaces between the grains of these minerals. No microcline nor microperthite is present in the sections.

An analysis of the rock by Prof. Norton Evans shows it to have the following composition:

SiO_2	43·67	per cent
TiO_2	·78	"
Al_2O_3	20·91	"
Fe_2O_3	3·54	"
FeO	8·01	"
Mno	·05	"
CaO	7·37	"
MgO	1·46	"
K_2O	2·25	"
Na_2O	6·73	"
P_2O_5	·11	"
CO_2	2·37	"
H_2O	2·52	"
	99·77	

The norm of the rock will then be as follows:—

Orthoclase	12·79	per cent
Albite	22·01	"
Anorthite	20·29	"
Nepheline	19·03	"
Olivine	10·58	"
Ilmenite	1·52	"
Magnetite	5·10	"
Apatite	·34	"
Calcite	5·41	"
	97·07	
Water	2·52	
	99·59	

Its position in the quantitative classification will be:—

Class III	Dosalane.
Order 6	Norgare.
Rang 2	Essexase (very near Salemase).
Sub-rang 4	Essexose.

Its mode or actual mineralogical composition is as follows:—

Orthoclase		2·78	per cent.
Albite	22·27	23·94	"
Anorthite	1·67		
Nepheline	15·91	26·23	"
Kaolin	10·32		
Hornblende		39·75	"
Apatite		·34	"
Calcite		5·50	"
		98·54	
Water		1·10	
		99·64	

Nepheline syenite, township of Monmouth, lot 11, concession VIII—(Second variety). The second variety which was examined is one in which the rock is richer in nepheline and poorer in iron-magnesia constituents, but which still contains much albite. It is much lighter in colour, but otherwise bears a general resem-

blance to the variety just described, being composed of the same minerals but in different proportions. Under the microscope all the constituents are seen to be fresh, but they frequently show signs of having been submitted to pressure, resulting in a more or less uneven extinction. This is especially marked in the case of the calcite, and the albite can in some few instances be seen to have been not only bent but actually fractured. The nepheline and hornblende also occasionally show strain shadows. As before, no microcline, nor microperthite, is present in the section, and a Thoulet separation shows that the rock contains no potash feldspar. The albite has a specific gravity of very nearly 2·61. The hornblende strongly resembles hastingsite, being a deep green colour, with marked pleochroism in deep green and pale yellowish green tints, a strong dispersion, small axial angle, and an extinction on the clinopinacoid of 30°.

In a single specimen it was found that the hornblende was replaced in part by a very deep green somewhat pleochroic pyroxene, around the individuals of which, and occasionally about the calcite grains, there is sometimes a narrow border of garnet. The pyroxene is evidently very rich in iron, and holds rounded inclusions of calcite and nepheline. The nepheline is fresh and presents the usual characters. There is probably a little sodalite present as well.

An analysis of the pyroxene-bearing variety of the rock by Prof. Norton Evans shows it to have the following chemical composition:

SiO_2	42·72	per cent.
TiO_2	·38	
Al_2O_3	25·08	"
Fe_2O_3	2·00	"
FeO	4·36	"
MnO	·16	"
CaO	6·92	"
MgO	·97	"
K_2O	2·69	"
Na_2O	11·02	"
P_2O_5	·19	"
CO_2	2·99	"
H_2O	·88	"
	100·36	

Its norm is as follows:—

Orthoclase	15·57	per cent.
Albite	7·34	"
Anorthite	10·80	"
Nepheline	46·58	"
Diopside	3·08	"
Olivine	5·10	"
Ilmenite	·76	"
Magnetite	2·78	"
Apatite	·34	"
Calcite	6·80	"
	99·15	
Water	·88	
	100·03	

Its position in the quantitative classification is:—

Class II.	Dosalane (very near Persalane).
Order 7	Italare.
Rang 2	Vulturase.
Sub-rang 4.	Vulturose.

If this rock possessed about one-half of one per cent less iron-magnesia constituents it would fall into the class of the Persalanes and would constitute the first dosodic domalkalic Tasmanare known.

The mode or actual mineralogical composition of the rock is as follows:

Albite	19·39	per cent.
Nepheline	50·57	"
Pyroxene	18·35	"
Garnet	1·45	"
Iron Ore	1·86	"
Apatite	·34	"
Calcite	6·80	"
	98·76	
Water	·88	
	99·64	

Nepheline rock, township of Monmouth, lot 10, concession VIII. (Third variety). Specimens representative of the third type were collected on lot 10, concession VIII of Monmouth, the outcrops of the underlying rock being made up essentially of nepheline and hornblende. These minerals occur in bands six or more feet in width, the different bands being traceable for long distances along the strike. The rock is coarse in grain, the white nepheline and black hornblende being strongly contrasted on a surface of fracture. The hornblende, as in other varieties of the rock, has a tendency to run in streaks in the direction parallel to the course of the band. On the weathered surface the rock has the pale grey colour, and presents the smooth surface assumed by nepheline when exposed to the weather, the black hornblende and albite standing out in rough relief. (See Plate LIX).

Under the microscope the rock is seen to consist essentially of nepheline and hornblende, with plagioclase, cancrinite, and calcite as accessory constituents, as well as sodalite, apatite, sphene, biotite, pyrite, and iron ores, these latter minerals being present in extremely small amounts.[1]

The nepheline occurs in large well-defined grains, presenting the usual characters displayed by the species. It is clear and fresh.

The hornblende is green in colour, the pleochroism and absorption being as follows: $\mathfrak{a}$= pale greenish yellow, $\mathfrak{b}$ and $\mathfrak{c}$ very deep green. The absorption is $\mathfrak{c} = \mathfrak{b} > \mathfrak{a}$. The maximum extinction observed in the sections of the rock was 19°. It is an alkali hornblende, containing less iron than hastingsite, but, like it, as shown by the calculation of the analysis of the rock, belonging to the division of the syntagmatites.

The plagioclase is present only in very small amount, and is in some cases untwinned, while in other cases it shows a faint, polysynthetic twinning. In thin sections it bears a very close resemblance to the nepheline, and when untwinned it is difficult in all cases to distinguish the two minerals. When a section is treated with acid and etched, however, the plagioclase is seen to occur in individuals of a more or less rounded form, or with curving outlines, lying between the nepheline grains or enclosed in the latter. The feldspar isolated from another variety of the rock

[1] F. D. Adams.—On a New Nepheline Rock, from the Province of Ontario, Canada. Am. Jour. of Sc., April, 1904.

PLATE LIX.

Monmouthite, township of Monmouth, lot 11, concession VIII. Nepheline (grey) with subordinate albite (white) and hastingsite (black).

in the same occurrence was found to be albite, and this felspar has, therefore, been taken as albite in calculating the mode of the rock.

The amount of cancrinite present varies very considerably in different specimens of the rock. In the specimen analyzed about 5 per cent was found. In other specimens more is found, although in no case is it very abundant. It is clear and colourless, but is at once distinguished from the nepheline when examined between crossed nicols by its much higher polarization colours, which in thin sections frequently rise to a blue of the second order. It is clear and free from interpositions, and in convergent light is seen to be uniaxial and negative. It also shows a slight but distinct dispersion of the bisectrices, giving a brownish and bluish tint on either side of the position of maximum extinction. When separated by Thoulet's solution, the mineral was found to have a specific gravity between 2·48 and 2·44, and to be readily decomposed when heated with dilute hydrochloric acid, with the evolution of carbonic dioxide, and with subsequent gelatinization. The cancrinite occurs in the nepheline in the form of narrow strings, or more rarely in little bunches of grains. These usually follow the course of minute cracks or cleavage lines, but also are frequently seen to follow the boundaries of individual grains of nepheline on their contact with grains of other minerals. Thus, between crossed nicols they appear as a brilliant edging about hornblende individuals, or about calcite inclusions in the nepheline, the small prismatic individuals of cancrinite being arranged with their longer axes at right angles to the contact, or to the course of the crack, as the case may be. The cancrinite has the appearance of being an alteration product of the nepheline.

Calcite occurs in large single individuals, which are found as inclusions in both the hornblende and the nepheline. The single individuals are often perfectly circular in outline, and the enclosing mineral is perfectly fresh and unaltered and is sharply defined against them. In other cases the same large calcite individuals lie between the other constituents of the rock, in all cases having the character of inclusions. They generally show very marked strain shadows, while the other constituents show little or no evidence of pressure phenomena.

The apatite is found as occasional more or less rounded individuals, enclosed in the nepheine or hornblende, but, like the other accessory constituents, merits no especial description.

An analysis of the rock made for me by Mr. M. F. Connor, B.Sc., gave the following results.

SiO_2	39·74	per cent.
TiO_2	·13	"
Al_2O_3	30·59	"
Fe_2O_3	·44	"
FeO	2·19	"
MnO	·03	"
CaO	5·75	"
MgO	·60	"
K_2O	3·88	"
Na_2O	13·25	"
CO_2	2·17	"
SO_3	trace	
Cl	·02	"
S	·07	"
H_2O	1·00	"
	99·86	

If, following the methods of the quantitative classification, the norm of the rock be calculated, that is to say, the proportion of standard minerals which would give a magma of this composition, or in the form of which the rock under other conditions of cooling might have solidified, this is found to be as follows:—

Anorthite	12·51	per cent.
Nepheline	67·72	"
Leucite	8·28	"
Olivine	3·70	"
Akermanite	·40	"
Magnetite	·70	"
Ilmenite	·30	"
Pyrite	·14	"
Calcite	4·92	"
	98·67	
Water	1·00	
	99·67	

This gives the rock the following position in the quantitative classification:—

Class 1—Persalane.
Order 8—Ontarare.
Rang 2—(Domalkalic).
Sub-rang 4—(Dosodic).

As this is the first Ontarare which has been described, the rangs and sub-rangs have received no names as yet. It is proposed, therefore, to call rang 2, Monmouthase, and sub-rang 4, Monmouthose, from the township of Monmouth in which this rock is found, while, as an ordinary designation, the name Monmouthite may be applied.

The mode, or actual mineralogical composition of the rock, is quite different from the norm, as given above, no leucite, anorthite, olivine, or akermanite being actually present. The mode is *abnormative*[1] to a striking degree.

The mode is as follows:—

Albite	1·83	per cent.
Nepheline	72·20	"
Sodalite	·28	"
Cancrinite	5·14	"
Hornblende	15·09	"
Hematite	·50	"
Calcite	3·12	"
Pyrite	·14	"
	98·30	
Water	·50	
Excess of Al_2O_3	1·20	
	100·00	

In calculating this mode the nepheline is taken as consisting of soda nepheline and kaliophyllite, in the proportions of 5 to 1, which is the composition of the nepheline of the nepheline syenite occurring further to the west in the area of the township of Dungannon.[2] One-half of the water found in the analysis is

[1] See Quantitative Classification of Igneous Rocks, p. 150.
[2] B. J. Harrington: Amer. Jour. Sc., Vol. XLVIII (1894) p. 17

considered as being present in the cancrinite, the remainder being regarded as belonging in part to the hornblende and as existing in part as hygroscopic water. This gives cancrinite in about the proportion in which it seems to be present in the thin sections of the specimens analyzed.

The various bases not required by the other minerals, and remaining over to form the hornblende are present in the proportions required to form syntagmatite; which are the proportions in which these bases are found in the hastingsite of the Dungannon nepheline syenite. The hornblende has accordingly been calculated as syntagmatite, using the theoretical values given by Zirkel.[1] This accounts for the existing percentages of all the constituents of the rock, with the exception of an excess of 1·20 per cent of alumina.

Of the rocks hitherto described, those which bear the closest resemblance to Monmouthite are the Urtites of the Peninsula of Kola.[2] These, however, belong to the class of the Dosalanes.

Another variety of the rock from lot 11, concession VIII, was found to contain scapolite in addition to albite and nepheline, together with a brown hornblende instead of hastingsite, and a little biotite. The scapolite which occurs in large amount shows good prismatic cleavages and is usually quite fresh. It has a specific gravity of 2·711, showing that it is near the meionite end of the scapolite series, and is accordingly rich in lime. On the south side of the Monck road, within the limits of the same mass, on lot 10, concession VII, a coarse pegmatitic variety of the syenite is seen, composed of two varieties of feldspar, one pale pink and the other white, together with a black hornblende of the hastingsite type. The weathered surface has a marked drusy character, probably owing to the removal by solution of calcite fragments which the rock originally contained.

To the south of this nepheline syenite mass the country is drifted until the Burnt river, on the front of concession VI is reached. Here, cutting the limestone, there are several large and very coarse-grained dikes of a pegmatitic development of the nepheline syenite. One of these, which crosses the river on lot 12, concession VI, consists of two feldspars, one pink and the other

[1] Lehrbuch der Petrographie, Vol. I, p. 303.

[2] W. Ramsay: Das Nephelinsyenitgebiet auf der Halbinsel Kola, Fennia, 15, No. 2, p. 22.

white in colour, together with a little black mica. Others holding a little nepheline occur on lots 10 and 11 of the same concession. On the former lot, and also on the line between lots 8 and 9 of the front of concession VI, there are several large dikes of nepheline syenite of a normal size of grain. One of them, from lot 10, concession VI, was examined microscopically and a separation of its constituents made by means of Thoulet's solution. The rock contains a large amount of a black hornblende possessing a very high lustre, which, under the microscope, is seen to be associated with albite, orthoclase, microcline, microperthite, nepheline, with a little biotite, pyroxene, and apatite. The microperthite is the most abundant form of feldspar and consists of an intergrowth of microcline and albite. It holds small inclusions of hornblende. The albite has a specific g vity of a little less than 2·62. The amount of microcline present is about equal to that of albite. The nepheline shows the usual characters. The hornblende is a variety which is probably referable to hastingsite. The biotite, which is not seen in every thin section, possesses a strong pleochroism in deep brown and yellow tints. The pyroxene occurs in very small amount and is green in colour.

The third group of nepheline syenite occurrences in the township of Monmouth, comprises a number of smaller developments, which are found in the extreme southwestern corner of the township on concessions II and III, between the large gabbro area on the north and the limestone flanking the Anstruther batholith on the south. The most easterly of these is a dike of the pink syenite phase of the magma, 30 paces wide, which crosses the road running south from Hotspur, on the front of concession IV. It is rather coarse in grain and generally uniform in character, but becomes very coarse in streaks. It is bounded by amphibolite on either side. The rock is composed of a pale pinkish feldspar and grains of magnetite, with a little biotite. No quartz and no nepheline can be seen in it, and the rock strongly resembles the pink syenite which passes into nepheline syenite at Kasshabog lake in the township of Methuen. Occasionally the iron ore occurs in large blotches on the surface of the rock, as is so often the case in similar occurrences in other parts of the area. The most interesting point in connexion with the rock is the occurrence in it of segregations or barrel shaped individuals of a white mica, which is exactly like that produced by the alteration of the corundum in Methuen.

There can be no reasonable doubt that these represent corundum which was formerly present in the rock and which has been altered to muscovite, but no corundum itself was found. If this dike were carefully prospected there is little doubt that corundum would be found at some point along its course. On its southern side this dike apparently passes into a typical quartz-bearing pegmatite; this latter rock certainly intervenes between the syenite and the amphibolite, and represents either a differentiation development of the dike itself, or a parallel quartz pegmatite dike which happens to be introduced along this line. The exposures do not enable the question to be definitely settled, but the probability is strongly in favour of the former explanation.

A band of true nepheline syenite, flanked by a curious gneissic rock, apparently an altered limestone (described on page 112), crosses Pine lake in a direction N. 30° E., from lot 10, concession III, on the south shore of the lake, to lot 11 of the same concession, on the north shore of the lake. The band is 80 feet in width, and is composed of a foliated nepheline syenite grey in colour and generally poor in nepheline, but containing segregations or *schlieren* of coarsely crystalline nepheline, sometimes as much as a foot in width.

Under the microscope, the rock presents a somewhat imperfect allotriomorphic structure. None of the constituents have good crystalline form, but come against one another along curving or straight lines, the feldspars sometimes interlocking with serrated borders. It is composed of microperthite, albite, microcline, orthoclase, nepheline, hornblende, and pyroxene, with accessory iron ore, apatite, sphene, garnet, and a mineral resembling zircon. The feldspars preponderate largely, and the microcline is present in considerable amount. The albite, which is well twinned according to the albite, and also often according to the pericline law, can sometimes be seen to send little curving arms into the microperthite. The hornblende has the characters of hastingsite. The pleochroism is strong and is as follows:

$\mathfrak{c}$ =deep green (almost opaque). $\mathfrak{b}$ = deep green. $\mathfrak{a}$ = greenish yellow. The pyroxene resembles it very closely in colour and general appearance, both minerals being very dark green. The pyroxene is also somewhat pleochroic in the same green tints as those shown by the hastingsite. The sphene occurs as a narrow border about some of the grains of black opaque iron ore, as does

also the biotite, while the garnet, which is pale yellow in the slide, occurs in the same way around some of the pyroxene individuals. The mineral referred to as resembling zircon has a very high index of refraction, and very high double refraction, and occurs in rounded individuals often traversed by numerous cracks. These grains occasionally have a rudely rectangular outline. They are either zircon, monazite or some allied mineral containing the rarer earths. The hornblende contains inclusions of both feldspar and pyroxene, and the rock in places shows some evidence of having been submitted to pressure in the distinct twisting of the albite individuals.

A band of nepheline syenite also crosses the road on the front of lot 10, concession III of Monmouth. It is the reddish, highly feldspathic phase of the rock and holds large individuals of nepheline, now completely changed to the greenish alteration product found in the similar rock from Brooks bay in the township of Methuen. (See page 301). It contains in places coarse segregations of magnetite and of biotite. Under the microscope, it is seen to be composed of microperthite, albite, microcline, orthoclase, nepheline (completely altered), biotite, iron ore, and a mineral resembling zircon. The feldspars constitute almost the entire volume of the rock, albite preponderating in some cases and microperthite in others, the latter showing remarkably beautiful intergrowths of the soda and potash feldspar. The nepheline, as has been stated, is now represented by an alteration product which resembles that described from the nepheline syenite of Brooks Bay and many other parts of the area. This has a specific gravity of 2·732, and is probably largely muscovite. Some of the sections contain biotite, while in others this is replaced by a deep green pleochroic pyroxene, with high extinction angle. In its contents of this mineral, and in the presence of the zircon-like mineral above referred to, this rock bears a marked resemblance to the nepheline syenite crossing Pine lake and described above. The zircon-like mineral possesses the same characters as in the Pine lake rock, but is rather more abundant, and seems, in addition to the cracks which traverse it, to possess a set of rude rectangular cleavages with extinction parallel to them. The iron ore which is present in small amount holds inclusions of the feldspar, while the feldspar holds inclusions of the nepheline, and *vice versa*.

Nepheline syenite is also well exposed, presenting a number of different varieties on this same road, where it crosses lots 2 and 3, concession III of Monmouth. The varietal forms are all coarse in grain, and run in bands or streaks coinciding with the strike of the associated rocks, and usually also show a parallelism in the arrangement of the constituents. In addition to the nepheline syenite of the ordinary types, several varieties are present which are of striking beauty when large weathered surfaces are examined. One of these is very rich in a brilliant black hornblende, which is hastingsite, or a hornblende closely allied to it. This, together with a light brownish red garnet, constitutes about 60 per cent of the rock, the other constituents being nepheline and albite in about equal amount. The latter mineral is white in colour, and stands out from the weathered surface with jagged crystalline outlines, while the nepheline, which is grey in colour and smooth, occupies depressions in the surface.

Another variety is entirely free from all dark constituents, and consists of a pale grey and white mass of nepheline and albite, with occasional large brownish red garnets, presenting a striking appearance. The rock holds a little calcite. A Thoulet separation carried out on a specimen of this variety showed that the nepheline had a specific gravity of slightly over 2·62, while the albite had a specific gravity between 2·59 and 2·62.

The only other rock in the township of Monmouth which might belong to the class of nepheline and alkali syenites is an occurrence which is exposed just south of an old lumber shanties by the side of the same road, on lots 7 and 8 of the rear of concession III. On the west this rock apparently passes into a banded white garnetiferous rock which looks somewhat like the albitic phase of the nepehline syenite; while to the east it is succeeded by a gabbro. The whole succession is cut off by the great gabbro mass which occupies the western part of concession IV. The rock in question is fine in grain, red in colour, and rudely foliated in character. A microscopic study shows that it is an alkali syenite, containing about 25 per cent of a rather light green hornblende associated with a little biotite. No quartz is present and the remainder of the rock is made up essentially of reddish feldspar. A Thoulet separation shows that of this feldspar about one-third is orthoclase and microline, another third albite, having a specific gravity between 2·58 and 2·62, while the remaining third has a

specific gravity a little greater than 2·62, and may be a very acid oligoclase. All these feldspars are distinctly red in colour, the colour in the case of the soda feldspars being, if anything, a little deeper than in the case of the orthoclase and microcline. The rock has a very perfect allotriomorphic or mosaic structure, such as that seen in many rocks which have undergone a complete recrystallization. The field relations of the rock cannot be determined with accuracy, partly on account of the presence of drift, and partly owing to the heavy forest which covers the district about here, and, while it has mineralogically certain affinities with the alkali syenites of the nepheline syenite series, it is somewhat different in appearance and character from any occurrence of these rocks which has been discovered elsewhere in the area.

3. NEPHELINE AND ALKALI SYENITES OF THE TOWNSHIP OF GLAMORGAN.

The township of Glamorgan lies immediately to the west of Monmouth, and its nepheline and alkali syenites have a very marked resemblance to those of the township of Monmouth just described. They all lie in the southeast corner of the township, where, as in Monmouth, they occur intimately associated with limestones. There is however one feature in which the Glamorgan occurrences are of especial interest, and that is, the frequent occurrence in them of enormously coarse-grained developments of the rock in the form of nepheline syenite pegmatites.

The first group of nepheline syenites to be mentioned are those which occur on lots 34 and 35, concession III, and, further west, on lots 30 and 33 of the same concession. These are crossed by the same road as that on which the nepheline syenites of the group last described from the township of Monmouth is exposed, and are closely related to them in character.

In the first mentioned occurrence the rock is very rich in iron-magnesia constituents, being made up almost exclusively of them. The second occurrence occupies a very considerable area in the district about the northeast arm of Trooper's lake, and is exposed along the road on the southern part of lot 32, and in isolated outcrops which protrude through the drift elsewhere within the limits assigned to the occurrence on the map. The occurrence on the road in the southern part of lot 32 is identical in appearance with the variety, rich in hastingsite, which

has been described from lots 2 and 3 of concession III of Monmouth, consisting essentially of nepheline, albite, and hornblende, with a smaller quantity of brownish red garnet. As accessory constituents, pyroxene, calcite, biotite, apatite, and zircon (?) are present. The hornblende which is present in large amount, is black by reflected light and deep green in the thin sections, and is a variety allied to, if not identical, with hastingsite. The pyroxene, when present, is very pale green in colour and occurs as inclusions in the hornblende. The calcite occurs either as rounded individuals enclosed in the hornblende or as grains of irregular shape lying between the other constituents. The nepheline in some slides is quite fresh, while in others it is seen to be altered in places to a zeolite, which has a low index of refraction but high double refraction, and which is probably natrolite. A Thoulet separation shows this mineral to have a specific gravity of between 2·17 and 2·24, while the specific gravity of the nepheline is a little greater than 2·62, and that of the albite a little less than this figure. This rock, while always rather coarse in grain, in places becomes very coarse, the individuals of the constituents of the rock attaining a diameter of a couple of inches.

The occurrences which protrude through the drift further north, about the middle of this lot, and also further south, on the north end of lot 32, concession II, have a coarse pegmatitic development, and consist of albite, nepheline, and black mica. Their exact mode of occurrence cannot in all cases be seen on account of the drift which surrounds them, but on the north half of lot 32, concession III, this same development of the rock is seen cutting the limestone in the form of great dikes; while on lot 32, concession II, it is seen in dikes of the same character, penetrating the gabbro and cutting abruptly across the course of its foliation. These dikes on lot 32 concession III, hold included masses of limestone, very coarse in grain. Crystals of zircon, dark reddish brown in colour, over an inch in diameter and each consisting of a double tetragonal pyramid, were also found in these dikes, as well as crystals of apatite.

The dikes on lot 32, concession II, in some cases become extremely coarse in grain. A specimen obtained from one of them consisted of a pyramidal mass of nearly pure nepheline, which measured 14 inches on the side and was composed of individuals of this mineral from three to five inches in diameter. The nepheline is in places slightly streaked with sodalite, and on the weathered

surface shows in places irregular shaped cavities which represent spaces from which masses of calcite have been dissolved.

Another important area of nepheline syenite is that which runs across concession IV from lot 27 to 32. It is very well exposed on lot 30, concession IV, on the property of Mr. Archibald McColl. The greater part of this mass consists of a light grey, well foliated nepheline syenite, containing a hornblende resembling hastingsite. A specimen of this which was examined microscopically was found to be composed of microcline, albite, nepheline, and hastingsite, with a little microperthite. Both microcline and albite are present in large amount. Inclusions of the former were observed in the nepheline. The rock is quite fresh and has the imperfect allotriomorphic structure usually seen in these foliated nepheline syenites.

In addition to this, which may be called the normal development of the rock, there are on the same lot other varieties. One of these is a very coarse pegmatitic phase of the rock, like that forming the dikes on lot 32, concession II, but even coarser in grain. One exposure of this is seen not far from Mr. McColl's house and has been opened up by blasting. Here the rock consists essentially of nepheline and albite, with occasional individuals or small masses of coarsely crystalline calcite. The iron-magnesia constituents are present in very small amount, and are over large surfaces entirely absent. They are represented chiefly by a black mica. A black hornblende, probably hastingsite, as well as a white mica, and a little pyrrhotite were also observed. The rock contains masses of pure nepheline as much as a yard in diameter. In fact, so far as can be ascertained, no nepheline rock so coarse in grain has hitherto been discovered anywhere. Sodalite is also present in the rock in places, occurring in irregular shaped masses, sometimes as much as two inches in diameter, enclosed in the large masses of nepheline, and having been apparently derived from them by some process of alteration. It was because the blue colour of this mineral was thought by certain experts to be due to the presence of copper that the occurrence was opened up by blasting and thus made more easy of examination. (See Plate LII.)

The relation of this pegmatitic variety to the normal variety of the rock cannot be ascertained with certainty, as their contact is covered by drift, but a true quartz orthoclase pegmatite occurs protruding through the drift in the immediate vicinity of the oc-

currence just described, in such a position as to suggest that it is a differentiated product of the same magma. A reddish syenite, containing some biotite, and similar to that found in so many other parts of the area in association with the nepheline syenites, also occurs in close association with the other varieties.

The largest body of these nepheline and alkali syenites in the township, is that having the form of a flat pear-shaped mass, which lies almost entirely in concession IV, extending from lot 19 across ten lots into lot 29, and enclosing a small body of amphibolite in its western part. It consists chiefly of the albite-syenite phase of the magma, often distinctly banded, and is well exposed on the two roads which cross it. On lot 26, concession IV, it contains the blotch-like segregations of magnetite often seen in these rocks, as well as crystals of zircon.

Another important and interesting occurrence is that, which in the form of a comparatively narrow band, is exposed at intervals along the Monck road immediately to the east of the village of Gooderham, on concessions V and VI, from lot 29 to lot 35, and then curving north with the strike of the country rock extends to the front of concession VIII. Just to the north of the road, on lot 29 of concession V, the rock is first seen as a pale grey granular syenite, containing in places a little nepheline and also holding a small amount of black mica. It so closely resembles the limestone through which it cuts, and to whose strike it conforms, that the two rocks are with difficulty distinguished from one another. On lot 31, concession VI, it is seen intimately associated with, and occurring as *schlieren* in, the great quartz pegmatite masses which here border and probably cut the granite-gneiss. In places on this lot it also holds nepheline, although never in large amount. A representative specimen collected by the road side on lot 32, concession VI, was found under the microscope to be composed essentially of microcline, biotite, and nepheline; in addition to which a triclinic feldspar (probably albite), and calcite were present in small amount, with accessory magnetite and pyrrhotite. The rock possessed a distinctly foliated structure.

Further to the east, on lot 34, concession VI, the grey granular syenite has red *schlieren* through it, which resemble in character ordinary pegmatite, but without quartz. Where at this place the grey portion of the rock becomes locally coarse in grain, large segregations of a white feldspar and nepheline occur.

This white feldspar, however, is found to have a specific gravity of 2·567, so that, while there may be a certain intergrowth of albite, it is essentially an orthoclase or microcline. The wall-rock here on the south is limestone, which is seen to be cut by arms of the nepheline syenite which run across the bedding. On lot 35 the nepheline syenite passes under a mantle of drift, but the rock is again exposed in its granular feldspathic phase on the town line, where the road between concessions VII and VIII meets it. This occurrence represents a phase of the rock which is poor in nepheline, while the feldspar is largely a potash variety, and one in which the nepheline syenite occurs in very intimate relation to and apparently passing into pegmatitic masses of the ordinary quartz-orthoclase type.

Only two other occurrences of nepheline syenite are known in the township of Glamorgan.

The first of these occurs at the extreme southeast corner of the township, on the south end of lot 35, concession I. Here there are large exposures of a variety poor in nepheline, the mineral being represented for the most part by the yellow alteration product (gieseckite) which replaces it in several occurrences already described. Even this is not abundant. The rock is reddish or greyish in colour, consisting essentially of feldspar of which there are apparently two kinds, one greyish and the other pinkish in colour, and a little biotite with occasional grains of magnetite. It possesses a streaked or banded structure and in places holds large segregations, sometimes as much as two feet in diameter, a very coarsely crystalline black mica, the individual plates of mica being several inches in diameter. A few little strings of muscovite, whose appearance strongly suggests that they are derived from the alteration of corundum, also run through the rock. No unaltered corundum, however, was observed.

The other occurrence is small but one which affords fine specimens of nepheline. It is situated at the southern end of lot 25, concession IV. The rock is pale grey in colour and consists of nepheline, a white feldspar (probably albite), a subordinate unt of a black mica, a few grains of iron ore, and a little muscovite. In the usual rather fine-grained variety there are very coarse-grained *schlieren* or segregations, from which nepheline individuals four inches in diameter may be obtained. The relations of the mass cannot be made out with certainty owing

to the drift and heavy bush which cover the contacts. It occurs associated with the gabbro of the great mass on the borders of which it lies, but how the two rocks are related to one another it was found to be impossible to determine with certainty.

4. NEPHELINE AND ALKALI SYENITES OF THE TOWNSHIPS OF HARCOURT, CARDIFF, AND WOLLASTON

The nepheline syenite occurrences in these townships are of comparatively small extent.

In the township of Harcourt, on lot 15, concession 1, there is a fine exposure of the nepheline syenite in a cutting on the Irondale, Bancroft and Ottawa railway. It is bounded on the north by the heavy band of crystalline limestone which sweeps around the northern end of the Cardiff batholith, the limestone being seen just north of the railway track, in large exposures consisting of nearly horizontal beds. The limestone here is nearly pure and free from admixture of silicates, but in some bands is dolomitic. The nepheline syenite appears to form a narrow selvage along the southern side of the limestone, and can be traced to the west across the neighbouring lots. To the south the relations of the syenite to the granite of the batholith are obscured by drift. The nepheline syenite has a banded structure, some bands consisting of almost pure nepheline, while in others the iron-magnesia constituents preponderate; there is also in many cases a variation in size of grain in different bands. Masses of coarsely crystalline calcite, evidently fragments from the adjacent limestones, are occasionally found as inclusions in the nepheline syenite, the nepheline and other constituent minerals of the latter growing into these inclusions, as if the latter were being replaced by them. Under the microscope, the nepheline syenite is seen to be composed essentially of nepheline and a deep green hornblende allied to hastingsite. The relative proportions of these two minerals vary in different slides. A considerable amount of calcite is present in large individuals, with irregular and usually curved outlines, which lie between the other constituents of the rock. A plagioclase feldspar and microperthite are present in very subordinate amount, together with a few rounded grains of sphene. The structure of the rock is allotriomorphic. None of the constituents possess any approach to good crystalline form, but come together along curved or straight lines and are quite irregular in shape.

About four miles to the east of this occurrence, and associated with the same band of limestone, Professor Miller[1] has observed a mass of white syenite carrying brown corundum. The rock is stated to form a hill about half a mile east of Leafield post-office in the northeast corner of the township of Cardiff, and was also found about half a mile southeast of the same point. No description of this rock is given, but it is apparently free from nepheline, and allied to the alkali syenites associated with the nepheline syenites in the township of Methuen and elsewhere in the area. This occurrence was not visited, but its position, as indicated by Professor Miller, has been shown on the Bancroft sheet.

In the township of Wollaston only a single occurrence of nepheline syenite is known, and this is a small one. It is found on the road which runs on the line between the townships of Wollaston and Faraday, on lot 9. On account of the fact that the country here is rough, the road does not follow the exact line on which it is supposed to be laid out, but winds to and fro across the boundary. On lot 9, at the point where the nepheline syenite occurs, it bends to the south and is almost exactly on the boundary. The occurrence, therefore, probably lies partly in Faraday and partly in Wollaston. Its position however is here taken as lot 9, concession XVI of Wollaston. The mass is peculiarly situated, forming as it does a solitary exposure, only twenty feet in width, surrounded by diorite.[2] In its immediate neighbourhood the surrounding rock is dark brown and rather rusty weathering, and was at first supposed to be a syenite, as it contains relatively more feldspar than is usual in the diorites of the area. A microscopic examination, however, showed that the supposed syenite was a gabbro diorite, bearing a close resemblance to that found on lots 20 and 21, concession IX of Wollaston. A Thoulet separation showed that the feldspar present was nearly all labradorite, although some of it was a little more acid, and some a little more basic than labradorite. In hand specimens the nepheline syenite is seen to be composed of nepheline, feldspar, a black mica, and occasional grains of magnetite. It has a more or less well-marked banded character and is usually coarse in grain. The relative abundance of the constituents varies more or less in different parts of the mass.

[1] Report of the Ontario Bureau of Mines, vol. viii, page 216.

[2] A somewhat similiar occurrence has been described by Ransome in the case of a nepheline syenite at Brookville, N.J. Am. Jour. of Sc., 1899, p. 426.

Under the microscope the rock is seen to consist essentially of nepheline, plagioclase, and biotite, while microcline, calcite, magnetite, pyrite, apatite, and zircon (?) occur as accessory constituents. The biotite usually occurs in rather large irregular-shaped individuals, which are strongly pleochroic, in colours ranging from a pale yellow to a very deep brown, basal sections being nearly black. It is sometimes found adjoining or partially surrounded by magnetite or chlorite, this latter mineral clearly showing its derivation from the biotite. The plates of biotite are frequently twisted. The prevailing feldspar is an albite, which, with the nepheline, in some places makes up the entire rock. As a rule it is fresh, occurring as large individuals and smaller grains, often showing fine polysynthetic twinning, the lamellæ being distinctly bent in some cases, and the mineral often showing strain shadows. Microcline is present in small amount, and microperthitic intergrowths are common. The nepheline forms large irregular individuals, frequently cracked and very turbid, this turbidity being due to incipient decomposition. Inclusions of small rounded grains of plagioclase and untwinned feldspar, as well as of calcite and biotite, are frequently found in the nepheline. Calcite is always present and is often abundant, occurring in large individuals. The shape of the grains indicate that it is derived from limestone inclusions. The twinning lines of the calcite are often curved in a striking manner. Both magnetite and pyrite occur in small amounts, the former being much more abundant. The pyrite in one or two cases is found partially altered to hematite, while magnetite forms a border around it. Little zircons (?) and a few grains of apatite possessing good crystallographic outlines are present in the section. The curved individuals of biotite, plagioclase, and calcite, and strain shadows, suggest that the rock has been subjected to great pressure.

A separation of the constituents of the rock was made by means of Thoulet's solution, which showed that the feldspar was almost exclusively albite, the potash feldspar present being quite subordinate in amount, but white in colour like the albite, and thus not to be distinguished from it in hand specimens of the rock.

One curious fact in connexion with this rock is that, while the nepheline syenite contains numerous large grains of calcite, which from analogy with other occurrences would naturally be

regarded as derived from the disintegration of included masses of limestone, no limestone was found within a mile of the exposure. So that while there may be inclusions of the limestone hidden by the forest covering which mantles much of the surrounding district, the small body of nepheline syenite seems to occur as an isolated mass within the great occurrence of di rite which underlies the northeast corner of Wollaston.

5. NEPHELINE AND ALKALI SYENITES OF THE TOWNSHIP OF METHUEN.

These rocks in the township of Methuen are confined to a single occurrence, which, however, is large and forms the most striking topographical feature in the township. This is known as the Blue mountain, a ridge which, rising abruptly from the plain about the middle of the township, stretches away to the southwest nearly as far as the Burleigh line, where it gradually sinks again to the level of the plain. It has an average height of somewhat over 200 feet above the level of Kasshabog lake, which lies immediately to the south of it, but at its northern end becomes considerably higher, reaching an elevation of 300 feet above the waters of the lake.

This ridge of the Blue mountain consists of nepheline and alkali syenites, while the surrounding country, as shown in the accompanying Bancroft map sheet, is underlain by amphibolites holding thin bands of crystalline limestone, and by granite-gneiss. The syenite mass, however, while forming the Blue mountain, can be traced beyond the limit of that ridge, but in continuation of its strike, to the southwest across the town line into the township of Burleigh as far as Stony lake, being exposed on the north shore of this lake, on the east side of concession XI of Burleigh, and also constituting one of the adjacent islands in the lake. The mass, however, attains its greatest width near its northeastern extremity, and becomes progressively narrower as it runs toward the southwest, that portion of it which lies within the township of Burleigh being merely a narrow band. It may thus be said to possess a slender pear-shaped outline, being eight miles long, and one and a half miles wide at its widest part near the northeast end, while the narrow southwestern part of the mass where it runs through the township of Burleigh has a width of only about two hundred yards.

The normal nepheline syenite of this occurrence is best seen in the northeastern part of the Blue mountain, where the mass

has its greatest areal development. It is light grey or white in colour, and of medium grain, being characterized, like all the syenites of this occurrence, by a very low content of iron-magnesia constituents. In the central and highest portion of this northeastern part, the rock is massive in character, but on eith r side develops a more or less well marked foliation or parallelism of constituent minerals, which, however, is not very striking on account of the small proportion of iron-magnesia constituents which the rock contains. The foliated structure is accompanied by a streaked or *schlieren* structure in the rock, which coincides with the strike of the foliation, that is with the direction of the longer axis of the ridge. The streaks consist of portions of the rock which are coarser in grain than the normal rock, or which contain some constituents more abundantly developed.

Specimens of the rock were collected from a number of localities in the northeastern part of the mountain, and the material from six of these localities has been sliced and studied microscopically. In some cases separations of the constituents have been made by means of Thoulet's solution. These localities were as follows:—Lots 20 and 21, concession VII, and lots 18, 19, 20 and 21, concession VI, of the township of Methuen. It will not, however, be necessary to describe them separately, as the rock is in all cases almost identical in character and composition.

Under the microscope the rock is seen to be very fresh, and to consist of albite, microcline, and nepheline, with which are associated very subordinate amounts of magnetite, with biotite or hornblende, or very rarely pyroxene. In some cases, but not usually, these two latter minerals occur together in the same rock. In some places muscovite is found, associated with and partly replacing the biotite. As accessory constituents, garnet, scapolite (?), and zircon (?) were observed, in very small amounts, and each in but a single specimen. These are the only constituents which were found.

The normal nepheline syenite is a variety which is highly feldspathic, and rather poor in nepheline. The feldspar is chiefly albite. This mineral is always well twinned according to the albite law, and occasionally this mode of twinning is combined with that according to the Carlsbad law. A series of measurements of the extinction of this feldspar in sections in the zone of

the base and the macropinacoid was made in slides of the rock from the highest point of the Blue mountain, and it was found that the maximum extinction on either side of the twinning line was 16°. A separation of the constituents by Thoulet's solution showed the feldspar to have a specific gravity of very nearly 2·60. The feldspar is thus proved to be albite, and similar separations carried out on specimens collected on lot 18, concession VI, and on specimens of the various differentiation products of the rock to be mentioned below, show that the plagioclase present in the rock is always albite, and that no feldspar more basic than this species (that is having a specific gravity greater than 2·60) occurs in the rock. The microcline is much less abundant than the albite, although it always occurs in considerable amount. There is, judging from the results of the Thoulet separations and the appearance of the rock in thin sections, from two to four times as much albite as microcline usually present. It is characterized by its very narrow cross-hatched twinning. The nepheline is usually quite fresh, but occasionally shows traces of alteration. It occurs in large irregular-shaped grains, and is uniaxial and negative. It is, on the whole, about equal to the microcline in amount, but locally becomes the preponderating constituent in the rock. The biotite is a very strongly pleochroic variety.

$\mathfrak{a}$ dark greenish brown, nearly black. $\mathfrak{c}$ pale yellow. Absorption $\mathfrak{a} > \mathfrak{c}$. The axial angle is very small. The hornblende is referable to the variety hastingsite. The small individuals possess a fairly good crystalline form, but the larger ones are irregular in shape, sometimes lying between the feldspathic elements of the rock, and sometimes enclosing them. It has an intense colour and a very strong pleochroism, as follows: $\mathfrak{a}$ green with yellowish tinge. $\mathfrak{b}$ deep green with bluish tinge. $\mathfrak{c}$ deep green. The absorption is $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. The dispersion is very strong, and sections at right angles to the optic axes are nearly opaque. The extinction is high, probably about 30°. The muscovite shows the usual characters of that species. The magnetite occurs chiefly in large individuals scattered sparingly through the rock and usually possessing a rude crystalline form. The garnet which was found in small amount in one specimen of the rock holding hornblende, is pale yellowish brown in colour, and identical in all its characters with that occurring associated

with the hastingsite in the Dungannon nepheline syenite, from which the latter mineral was originally described.[1]

As has been mentioned, the rock often possesses a streaked or *schlieren* structure, due to a coarser grain or difference in mineralogical composition in some portions of the rock. The coarsely crystalline streaks usually consist of albite and nepheline, individuals of the latter mineral seven inches in diameter having been observed in one case. Sodalite was observed in association with the coarse-grained nepheline in a few places.

The rock has a granular structure, on which the faint gneissic and the *schlieren* structures are superinduced, blocks of the rock resembling a somewhat impure crystalline limestone or marble. Under the microscope the structure is seen to approach closely to an allotriomorphic development. In one case a minutely miarolitic structure was seen.

The pyroxene, which species, as has been mentioned, is occasionally found in the rock, was found most abundantly in the nepheline syenite forming the summit of the ridge on the southern part of lot 17, concession VIII of Methuen. Here it is, with the exception of a few crystals of magnetite, the only dark constituent of the rock, but occurs in very small amount. It is bright green in colour, and distinctly pleochroic, with a small angle of extinction, and is probably acmite.

A fine development of the nepheline syenite is also seen forming high white cliffs at the western end of Mountain lake, on the north side of the lake, on lots 13 and 14, concession X of Methuen. This rock consists of about one-third nepheline and two-thirds feldspar. It is almost free from iron-magnesia constituents. Under the microscope it is found to be composed of albite, microcline, and nepheline, with accessory magnetite, biotite, and muscovite. A Thoulet separation of the rock showed that no feldspar more basic than albite was present, and the separated microcline was quite white and could not be distinguished in colour from the albite.

In a rather more micaceous specimen of the nepheline syenite from the Blue mountain, collected a short distance further east, on lot 15, concession IX of Methuen, a small quantity of spinel, in

[1] Adams, F. D., and Harrington, B. J.—On a new Alkali Hornblende and a Titaniferous Andradite from the Nepheline Syenite of Dungannon, Hastings county, Ontario. Am. Jour. of Science, March 1896.

little rounded individuals, was observed in the thin sections. The occurrence of this mineral is of interest as showing that the magma here contained a slight excess of alumina, which separated in combination with magnesia as spinel, while, as mentioned below the much larger excess of alumina in other parts of the mass separates out as corundum.

The normal nepheline syenite in places becomes rather finer in grain and poorer in nepheline than usual. One of the best developments of this variety is to be found on the summit of the ridge of the Blue mountain, about the middle of lots 13 and 14 concession X of Methuen, where it is seen in large exposures. Under the microscope it is seen to be composed chiefly of albite, with a considerable admixture of microcline and a smaller amount of nepheline. Muscovite and magnetite, both very subordinate in amount, are the only other constituents present. The rock merits no further description, since its structure and the character of its constituent minerals are identical with that of the nepheline syenite already described. It differs from the normal nepheline syenite in containing less nepheline, and in having muscovite as the non-feldspathic constituent.

A chemical analysis of this rock, by Professor Norton Evans of McGill University, gave the following results:—

SiO_2	59·68
TiO_2	none
Al_2O_3	[illegible]·48
Fe_2O_3	59
FeO	·37
MnO	none
CaO	·26
MgO	·21
K_2O	4·68
Na_2O	9·52
P_2O_5	none
CO_2	·04
H_2O	·66
	99·49

The norm of the rock when calculated is found to be as follows:

Orthoclase	27·80 per cent.	
Albite. . .	49·25	"
Anorthite. .	1·25	"
Nepheline	16·76	"
Corundum	2·24	"
Olivine	·45	"
Magnetite	·93	"
	98·68	
Water. .	·66	
	99·34	

Its position in the quantitative classification is:

Class I.	Persalane.
Order 6.	Russare.
Rang 1.	Miaskase
Sub-rang 4.	Miaskose.

The mode or actual mineralogical composition of the rock is as follows:

Orthoclase		16·12 per cent.	
Albite. . .	53·45	54·70	"
Anorthite. .	1·25		
Nepheline		18·18	"
Muscovite . .		7·95	"
Biotite		1·27	"
Magnetite .		·93	"
		99·15	"
Water .		·28	"
		99·43	

In this calculation the potash and soda molecules in the nepheline are taken as being present in the relative proportion of one to five, which is the proportion in which they have been shown by analysis to occur in the nepheline of this district. The proportion of albite and anorthite, however, is greater than ten

to one, which means that some of the albite is united with the orthoclase in the form of soda orthoclase.

Associated with the nepheline syenite there occurs in places a rather remarkable looking syenite, pale and reddish or pink in colour, and, like the nepheline syenite, almost free from iron-magnesia constituents. It occurs as *schlieren* in the normal rock passing imperceptibly into it, but is chiefly confined to the sides of the occurrence, although not continuously developed about it. It is seen along the northern border of the mass, from lot 22 of Methuen to Stony lake, and forms the southern border of lots 14, 15, and 16 of Methuen.

The colour in the case of the reddish variety is apparently due to the greater abundance of very minute reddish inclusions which occur in both feldspars indiscriminately, and whose presence seems to be accompanied by the alteration of any nepheline which may be present to a peculiar gieseckite-like aggregate described below. The reddish colour in fact seems to be due to an incipient alteration of the rock, which is chiefly seen about the sides of the mass.

The reddish syenite is typically developed about a quarter of a mile west of the locality from which the nepheline syenite whose analysis has been given above, was obtained. It is here traversed by the veins which are being worked for corundum. It is first seen to occur as streaks or *schlieren* in the white rock and on going west replaces the latter. The syenite here has a pale reddish or pinkish colour, and is rather fine and even in grain. The iron-magnesia constituents, which are very subordinate in amount, occur associated together, forming little elongated dashes, giving a species of foliation to the rock.

Under the microscope the rock is seen to be composed essentially of albite and microline. The twinning of the microcline is very narrow, and there is some untwinned feldspar which is apparently orthoclase. The only other minerals present are biotite, magnetite, pyrite, calcite, and quartz. These occur intimately associated, and form the little dark coloured dashes seen in the hand specimens. They are all present in small amount, the magnetite often having a rude crystalline form. The calcite occurs in irregular-shaped individuals, and is occasionally seen away from the dashes, lying between the feldspar grains. It is not seen in all sections. The quartz, like

the calcite, does not occur in all sections, and when present is found with the calcite in rather large irregular-shaped grains. These two constituents may be secondary products, although not ordinary decomposition products, for the rock is very fresh.

The rock has an allotriomorphic structure, approaching nearly in character to the mosaic or pavement structure seen in metamorphic rocks.

A chemical analysis of the rock, by Professor Norton Evans, gave the following results:—

SiO_2	65·89	per cent.
TiO_2	none	
Al_2O_3	19·73	"
Fe_2O_3	2·03	"
FeO	·75	"
MnO	trace	
CaO	·46	"
MgO	·27	"
K_2O	3·95	"
Na_2O	6·59	"
P_2O_5	none	
S	undet.	
CO_2	·44	"
H_2O	·34	"
	100·45	

The norm of the rock is as follows:

Orthoclase	23·35	per cent.
Albite	55·54	"
Anorthite	2·22	"
Quartz	11·22	"
Corundum	3·77	"
Hypersthene	·70	"
Magnetite	2·32	"
Pyrite	·48	"
	99·60	
Carbonic acid and water	·78	
	100·38	

The amount of pyrite is calculated by assuming that the excess of ferric iron over the amount required to form magnetite with the ferrous oxide, is united with sulphur.

The position of this rock in the quantitative classification is as follows:

Class I . . . . Persalane.
Order 4. . . . . Britannare
Rang 1. . . . . Liparase.
Sub-rang 4. . . . . Kallerudose (near Nordmarkose).

If, however, the calcite be regarded as secondary and its lime be calculated as anorthite on the supposition that it was really present in the original magma, while the carbonic acid was not; this increase of salic lime will be just sufficient to carry the rock over into Order 5 and thus make it a Canadare with the subrang Nordmarkose. Mineralogically it differs from the white syenite just described in containing no nepheline or muscovite, but a little quartz. The mode of this rock is nearly normative, that is, the actual mineral composition is nearly that set forth in the norm. The hypersthene of the norm belongs to the biotite of the rock, the former mineral not being actually present. The calculation shows that there is really relatively more albite present in proportion to the orthoclase than would be supposed from a study of the thin sections. It also shows that there is rather more quartz present than would be expected from an examination of the hand specimens or the slides, and also that the rock must contain some free alumina in the form of corundum, although this mineral does not happen to occur in any of the thin sections which have been prepared of the rock from this particular locality. As has been mentioned, however, corundum is found abundantly in the veins or dikes of syenite pegmatite which cut the rock at this locality. The occurrence of free quartz and corundum in the same igneous rock appears to be an anomaly. If, however, the quartz be secondary the anomaly disappears.

Where this reddish syenite, a mile and a quarter to the southwest of the locality just described, crosses the road running north from Lake Kasshabog to Jacks lake, on lot 6, concession XII of the township of Burleigh, it in places holds corundum in large amount. Under the microscope the rock is seen to

consist of albite, microcline, orthoclase, biotite, muscovite, and corundum. The albite preponderates largely in amount over the potash feldspars. Biotite is present only in very small amount, but there is a considerable percentage of muscovite, in irregular-shaped individuals which have a tendency towards a lath-shaped development, and which often occur in groups, which frequently penetrate one another and also penetrate the feldspars.

The corundum occurs as individuals about half an inch long, which are especially abundant in streaks following the strike of the rock. In the thin sections it is invariably seen to lie embedded in the muscovite in the form of very irregular-shaped grains, rounded or corroded in appearance. Each corundum grain has a single large individual of muscovite enclosing it, or occasionally there are two or more smaller grains of corundum within the single muscovite individual, which look as if they had originally formed part of one larger individual. (See Plate LIV). The muscovite outline often in a general way conforms to that of the corundum core which it contains, as shown in the accompanying microphotograph of a thin section of the rock. (See Plate LX).

The corundum has the usual high index of refraction, and a double refraction which usually gives yellows and reds of the first order, but in some cases, even in good sections, gives a blue of the second order. As has been mentioned elsewhere, the colours which this mineral gives in thin sections are usually higher than would be expected, on account of the fact that owing to its hardness it always remains somewhat thicker in the finished section than the minerals with which it is associated, and can be seen distinctly standing up from the surface, if the slide is examined before the cover glass is placed upon it. It often contains minute opaque black inclusions, which in the basal sections appear as irregularly rounded plates, but in sections parallel to the vertical axis of the crystal, as rods. In the last mentioned sections the extinction of the corundum is parallel to the direction of the rods, so that these latter are inlaid parallel to the base.

It is impossible to determine from the sections whether there is a constant orientation in the case of the corundum and muscovite. In one case, however, the basal plane of the corundum, marked by the inclusions, lies in the direction of the vertical axis of the enclosing muscovite individual.

PLATE LX.

Microphotograph of corundum enclosed in muscovite. Red syenite. Just west of Blue mountain, Methuen, Ont. Between crossed nicols. Magnified 72 diameters.

In addition to the dark inclusions just mentioned, the corundum occasionally encloses minute rounded grains of a deep green isotropic mineral, which have the characters of spinel. In one or two cases, larger grains of this mineral are seen associated with the corundum.

The reddish syenite is also seen along the southeastern side of the Blue mountain, forming the margin of the intrusion. It crosses Brooks bay, which is the most northerly portion of Kasshabog lake, extending from the west side of lot 14, concession VIII, as far as the southeast corner of lot 17, concession VII of Methuen. On the north it passes into a rather fine-grained variety of the nepheline syenite, poor in nepheline, like that of which an analysis is given above, and then into the nepheline syenite of the main body of the intrusion.

The reddish syenite from several places along this band was examined, and was in all cases found to be identical in character. It is composed of albite and microcline, with a small percentage of biotite. A few scattered crystals of magnetite can be seen in the rock in some places and on the west side of Brooks bay a very little calcite occurs, in small rounded grains. In most places the rock also holds a small amount of a mineral which is now completely changed to a gieseckite-like alteration product. The rock contains from two and a half to three times as much albite as microcline. The gieseckite is yellow on the weathered surface, but on fresh surfaces of the rock it has a pale green or a pink colour. It has a hardness of four, and is quite dull and lustreless. A rough quantitative analysis of a specimen, by Mr. O. E. Leroy, showed it to possess the following chemical composition:—SiO_2, 45 per cent; Al_2O_3 (with a little Fe_2O_3), 38 per cent; MgO, 3·6 per cent; CaO, 2·2 per cent; H_2O, 7·8 per cent; K_2O, not determined.

This represents the chemical composition of the aggregate known as gieseckite, which is an alteration of nepheline commonly found in other parts of the world. Here also it is evidently an altered nepheline, for although in the pink syenite the change is always complete, no unaltered nepheline remaining in the rock, in the white variety of the syenite in a few places the nepheline can be seen in process of alteration into such an aggregate. A similar material is also produced by the alteration of the nepheline in the nepheline syenite in one part of the township of Monmouth,

and has already been described (see page 281). As has been mentioned, the nepheline syenite mass forming the Blue mountain extends to the southwest in the form of a narrow belt, and eventually disappears under the waters of Stony Lake, on concession X of the township of Burleigh. It is well exposed on the shore of the lake, and also on a small island situated a short distance from the shore. The band here consists of a grey nepheline syenite flanked on either side by pink syenite. The two rocks pass into one another and both have a somewhat gneissic structure. They can be seen to send dikes into the limestone which lies to the west of them, and to hold inclusions of it. Both on the shore and on the island segregations of corundum are occasionally found in the pink syenite, and occasionally on the island the same mineral is seen in the nepheline syenite. The rocks when examined microscopically are found to be identical in character with the occurrences already described from the Blue mountain.

As has been mentioned, both the nepheline syenite and the reddish syenite frequently contain coarser grained streaks or *schlieren*. In this respect they resemble many of the granites of other parts of the area, as mentioned in describing these rocks. These coarser streaks usually coincide in direction with the foliation of the rock, but in some cases they can be seen to cross the foliation of the syenite and even to penetrate the rock of the surrounding country. In this way again they agree with the similar occurrences in granite; they are in fact the pegmatitic phase of this nepheline syenite and syenite magma, and what has been said of the structure of the granite pegmatites and their relation to the granite (see page 139), is applicable here and need not be repeated.

These pegmatites are composed of the same constituents as the normal rock, and in several places on and about the Blue mountain they have been opened up by mining operations, in order to obtain from them one or other of two minerals, which, in them, come to be of economic value; namely, muscovite, and corundum. The muscovite, which is a common constituent of the syenite in some of these pegmatite dikes, occurs in plates several inches in diameter; while the corundum, which is often an accessory constituent in the syenite, in several of these dikes occurs in considerable amount. In these cases there must have been a concentration of alumina in the residual magma from which the pegmatites

PLATE LXI

Muscovite with some inclusions or cores of corundum, lot 14, concession IX, Methuen township

were derived, but it would seem that on the whole these pegmatites and the rock itself have approximately the same composition. The pegmatites which are worked for muscovite and corundum, however, do not here as a general rule contain nepheline, or if this mineral be present it is only in small amount, and is often represented by gieseckite, and they are thus for the most part the pegmatitic form of the syenitic phase of the nepheline syenite magma, and usually have this for the wall rock. A description of several of the more important of these occurrences has been given under the headings of mica and corundum in the section of this report dealing with Economic Geology (page 368). Reference is there made to a remarkable mode in which the corundum often occurs in these dikes, the corundum individual being enclosed in muscovite, and generally in a single large crystal of this species, the corundum core having a smooth surface and rounded shape, as if the mica had resulted from the alteration of the outer portion of the corundum crystal. The corundum is often so completely enclosed in the muscovite that it is not discovered until the mucovite crystal is split open and the core of corundum thus exposed. This phenomenon, occasionally seen in the corundum deposits in the Craigmont district, is here in Methuen shown in a striking manner and especially in the openings on lot 13, concession X, and at Drains mine on lot 17, concession VII. (See Plates LIV, LV, LX, LXI, and LXII).

The origin of this association is discussed elsewhere (see page 249).

On lot 13, concession X, the corundum is of a greenish grey colour, often changing to blue in the centre of the crystal. The colour suggests sapphire, but the mineral is opaque, or at best translucent. At Drains mine the corundum is greenish grey in colour, and has associated with it, in addition to the muscovite and feldspar, a black biotite, probably lepidomelane, and a little magnetite, schorl, and gieseckite. The pegmatite mass is not sharply separated from the wall-rock, but passes, though rather abruptly, into it.

The corundum, however, does not always occur mantled by muscovite, but is frequently found enclosed in feldspar or in grains or crystals scattered through the mass of the syenite.

The contact relations of the Blue mountain *massif* to the amphibolite series, which almost entirely surrounds it, are distinct. The syenite is intrusive, breaking through the amphi-

bolites and sending arms into them. On the Blue mountain, when going from the central part of the intrusion toward the northern contact, the reddish syenite first appears in streaks in the nepheline-bearing syenite, and then comes in more abundantly along the contact, constituting the whole mass. The reddish syenite, especially near the contact, can in places be seen to hold quartz, and dark coloured inclusions appear in it abundantly. These often have the appearance of having been more or less softened and drawn out in the moving magma, and are apparently fragments of the amphibolite country rock. One of these *schlieren*-like fragments, when examined under the microscope, was seen to be composed of plagioclase, microcline, and an untwinned feldspar, but to differ in a marked manner from the enclosing syenitic rock in containing a considerable amount of hornblende as well as biotite. This fragment-filled belt can be traced all along the northwestern border of Blue mountain. At the termination of the ridge to the northeast the mountain sinks rapidly to the level of the plain. The character of the contact here is not well seen, but the road which passes around the end of the mountain is on nearly level ground, is nowhere over fifty feet above Kasshabog lake, and shows blocks and occasional exposures of a grey amphibolitic gneiss, and an intercalated band of crystalline limestone. On the southeastern side of the ridge the syenite is bordered along the greater part of its extent by the same amphibolites, with occasional thin bands of intercalated crystalline limestone, but for a portion of its course comes directly against the granite of the Methuen batholith. The contact of the syenite intrusion and the granite can best be studied on the shores of Brooks bay, which forms the northwestern extremity of Kasshabog lake, although even here the relations are not clear, owing to the fact that the actual contact is concealed by a strip of marsh. The granite of the batholith, however, near the contact is very poor in quartz and resembles in a striking manner, both in composition and structure, the pink syenite of the mountain.

It is, therefore, quite certain that the nepheline and associated syenites of the Methuen area form an intrusive mass, breaking through the metamorphic series, consisting chiefly of amphibolites with thin bands of crystalline limestone, which underlies this part of the township. The resemblance of the two rocks when they approach each other, and the close genetic connexion

of the nepheline syenites with granite in other parts of the area would suggest that the two rocks here form part of the same intrusion; but on the other hand the areal distribution of the rocks in question, here, and their relations to the metamorphic series which they both cut, point strongly to the great Methuen batholith as a second and later intrusive mass, which cuts through both the amphibolite series and the nepheline syenite, the latter being an intrusion of earlier date.

6. NEPHELINE AND ASSOCIATED ALKALI SYENITES OF FARADAY, DUNGANNON, MONTEAGLE, RAGLAN, AND BRUDENELL.

From the northwest corner of the township of Faraday an extensive, and what is believed to be a continuous belt of nepheline syenite, sometimes accompanied by the closely related red syenite, extends in a southeasterly direction for a distance of about three and a half miles, crossing the Monck road on lot 26 between concessions A and B. Near this place there is a gradual change in the strike of the rock, the band curving around and running in a direction a little north of east, or parallel to and in the immediate vicinity of the Monck road, for an additional length of nearly three miles, as far as lot 16, in concession A. It is impossible to trace its further extension eastward without some rather serious interruptions, as only occasional outcrops were found protruding through the rather extensive and deep covering of drift. It seems, however, entirely reasonable to assume that the several exposures found, all belong to one continuous belt, for, as the village of Bancroft is approached, there is a very marked increase in the area over which these syenitic rocks are distributed. Throughout this interval the width of the band varies greatly, in some places measuring half a mile or even more across the strike, as in concessions XV and XVI, while at other points, as at the crossing of the Monck road, an interval of only a few yards intervenes between the boundaries of the intrusion.

Careful examination would also doubtless show that this same band is more or less continuous in a northwesterly direction across the southwest corner of Herschell, and into the adjoining township of Cardiff, where in the vicinity of Leafield P.O., occurrences of the closely related white alkali-syenite have been noted by Dr. Miller. Farther to the northwest, and possibly representing outcrops of the same band, nepheline syenite has been found and described, as crossing the Irondale, Bancroft and Ottawa railway, on lot 15, concession I of the township of Harcourt.

At its intersection with the Hastings road at the village of Bancroft, between Faraday and Dungannon townships, the nepheline syenite measures over half a mile across its strike, which is here nearly east and west. East of Bancroft these syenitic rocks increase very rapidly in volume, attaining their maximum development in the vicinity of Bronson P.O., where extended and often rather continuous outcrops may be found for a distance of over [illegible] miles, in a north and south direction, underlying [illegible] between the eleventh and fourteenth concessions as [illegible] York river. (See Plates XLVIII, XLIX and L).

[illegible] valley of the York river, and extending in a general direction [illegible] east of north from the bridge over the York river, [illegible] concession, to the mouth of Papineau creek in [illegible] there are a large number of lenticular masses of [illegible] alkali-syenite, intruded along the strike of the crystalline limestones and amphibolites usually described as belonging to [illegible] ville series. Time did not permit such a detailed examination of this valley as would be necessary to accurately outline or even locate all such masses, even if such a thing were possible, with the great accumulation of drift material, but the position of a few of them are shown on the map. Near the mouth of Papineau creek the York river turns rather abruptly from a northerly to an easterly direction, the strike of the rocks showing a correspondingly sudden divergence. A little east of Papineau creek, and on both sides of the river, nepheline syenite has been noticed intruded through the crystalline limestones. Farther down the river and a little north of Fosters rapid an extremely basic nepheline rock occurs. Still farther to the east Dr. Miller mentions nepheline syenite as outcropping on a ridge about half a mile northwest of Campbells bridge, across the York river, in concession IX of Carlow. No very detailed examination has been made of the area between Carlow and Brudenell, but the closely related corundum syenites occur in concessions XVIII and XIX of Raglan, and concession I of Radcliffe close to Palmer rapids on the Madawaska river, while nepheline syenite has been found on lot 25, concession XIX of Raglan. All of these last mentioned Raglan and Radcliffe occurrences, however, seem to belong to another and parallel band of these syenitic rocks, which, starting from lot 14, concession XIV of the township of Carlow, where corundum

was first discovered by Ferrier, extends eastward through the two northern concessions of Raglan, having been traced a short distance east of the Madawaska river near Palmer rapids. The occurrences of nepheline syenite, and the closely related red syenite in concessions V and VII in the western part of the township of Brudenell, with their northwest and southeast strike, cannot be correlated with either of these bands, although they occupy an intermediate position between these and the Algona and Sebastopol occurrences to the east. Extending eastward from Brudenell a very wide belt of rocks of closely related syenitic type covers the northern portions of the township of Lyndoch, extending thence into Sebastopol as far as Clear lake and no doubt beyond. The nepheline syenite found in the first concessions of Algona and Sebastopol by Dr. Miller occur in the same tract of country.

These syenitic rocks therefore occupy a practically continuous strip of country, extending from the northwest corner of the township of Faraday to the York river in the township of Dungannon, a distance of over sixteen miles. From this point down the valley of the York river, and thence through Carlow, Raglan, Brudenell, Lyndoch, Sebastopol, and Algona townships, numerous and extended outcrops have been recognized. The extent and continuity or otherwise of the numerous outcrops noticed is very difficult of determination, owing not only to the inaccessibility of much of the area in which these outcrops occur, but also to the extensive covering of drift material and the dense growth of forest trees. All of the occurrences, however, seem to be confined to a definite strip of country, which extends in a general northeast direction through the townships already mentioned, for a distance of about forty miles from the York river bridge.

The almost invariable association of these nepheline syenites with the crystalline limestones is a fact which has been commented upon by all geologists who have examined these occurrences. This intimate connexion moreover is regarded as more than accidental, although so far no satisfactory explanation has been advanced to account for the apparent close relationship existing between two types of rock differing so widely in origin and composition. On a large scale in the field the relation of the nepheline syenite and the crystalline limestone may be studied from point to point, the line of junction often showing a most curious and intimate commingling of the material of both rocks, so that fre-

quently it is impossible to decide in regard to certain individual outcrops whether they should be classed with the syenite or the limestone. The explanation regards the nepheline syenite as quietly invading the limestone, the magma slowly eating into and replacing an equivalent volume of the sedimentary material.

All stages in this interesting and somewhat unusual phenomenon are well seen in the Central Ontario railway cutting in the town of Bancroft, and may be studied and represented by specimens showing on the one hand nepheline syenite with fragments only of the invaded limestone remaining in the form of sharply bounded grains of calcite, while corresponding with this at the other extreme may be noticed large portions of the crystalline limestone with imbedded and comparatively large individuals of nepheline, biotite, and other characteristic minerals of the syenite. Consideration of these facts, moreover, explains in a very satisfactory manner the presence of the grains of calcite so frequently seen under the microscope in the thin sections of this rock. These grains of calcite with perfectly sharp outline are sometimes completely enclosed in perfectly fresh and normal nepheline, hornblende, and other component minerals of the syenite. There are no signs whatever of secondary action, or decomposition, or anything even suggesting the presence of this mineral as an infiltration into or among the other constituents, all of which are fresh and unaltered. This somewhat anomalous, though by no means unique occurrence of calcite, in a rock of undoubtedly igneous origin, and its eminently primary habit, has for a long time been a puzzle to petrographers, many of whom have not been able to satisfactorily or fully account for its presence in this connexion. Holland[1] in commenting on the eminently primary habit of the calcite developed in the nepheline syenites of India says, "the low silica percentage in this group of rocks removes the chief theoretical difficulty to its crystallization from a molten magma as a normal constituent of an igneous rock." Hogbom[2], from his studies of the nepheline rocks of the Island of Alno, tends to show that the large masses of crystalline limestone, as well as the scattered grains of calcite, have been fused in the magma without decomposition, and that during solidification the calcite has been developed out of the magma in

[1] Mem. Geol. Surv. India, vol. xxx, part 3, 1901, p. 197.

[2] Geol. Foren. i. Stockholm Forhdl., vol. xvii, 1895, pp. 100 and 214. Abstract in Mining Mag., vol. xi, 1897, p. 250, and Rosenbush, Miks. Phys. 1896, pp. 169 and 171.

precisely the same manner as the other component minerals. At none of the localities, however, where these syenites have hitherto been examined and described are the conditions for study so complete and satisfactory as in Ontario, for elsewhere the large masses of the invaded limestones either do not now exist or have not yet been recognized. This absence of the limestones may be due quite possibly to their having been wholly replaced by the syenite, or they may have been removed as a result of subsequent erosion. It seems more reasonable, however, to suppose that later and more detailed examination, especially of the Indian locality, will show the immediate proximity to the syenites of considerable areas of crystalline limestone, thus completing their surprising analogy with the Ontario occurrences. (See also pp. 232 and 233).

Nepheline Syenite and Craigmontite.

The term syenite as applied to developments of this rock, at least in the central and northeastern portions of the syenitic band, is somewhat of a misnomer, for plagioclase, varying from albite through oligoclase to andesine is the prevalent, and often the only feldspathic constituent. Microcline, orthoclase, and microperthite do sometimes occur, but these are always subordinate in amount, and must be regarded as accessory or accidental constituents.

The nepheline syenite is sometimes quite massive in structure, although usually it possesses a more or less perfect foliated and occasionally schistose structure. (See Plate XLIX). It varies in texture, from medium to coarse-grained, the pegmatitic phases sometimes exhibiting almost pure nepheline individuals, sometimes as much as a yard in diameter, with correspondingly coarse plagioclase. The nepheline is more susceptible to weathering processes than the plagioclase, and as a consequence occupies well marked depressions or pits, with smoothly rounded surfaces of a pale greyish or cloudy appearance. The plagioclase on the other hand stands out with prominent angular relief, usually of a pure chalk-white colour.

Nepheline may occur in very variable quantity, in some extreme cases completely replacing the feldspar, while, at other times, only occasional individuals can be distinguished.

Some portions of the Brudenell outcrops exhibit a rock made up entirely of nepheline and a much smaller proportion of biotite,

together with a considerable proportion of dark green spinel (automolite). Specimens of the nepheline syenite at Craigmont can readily be obtained, showing over 75 per cent of nepheline. Thin sections prepared from some of the specimens representative of occurrences near the York river, and between this point and Bancroft, of both the biotite and hornblende phases, show only occasional and small individuals of plagioclase, the rest of the rock being made up almost altogether of nepheline, with a much smaller proportion of biotite and hornblende. Some portions of the syenite, forming outcrops near the extreme northeast end of the band in the first concession of South Algona, are very coarse in grain, and the nepheline occurs in it in large sized pieces.

As the precise chemical and mineralogical composition of the several varieties of the nepheline syenite have already been definitely ascertained, and included along with the detailed descriptions of occurrences in the southwestern extension of this immense belt of syenitic rocks, it will be necessary here merely to supplement these, when necessary, by descriptions of such types as seemed to show a considerable divergence from those previously studied. Such being the case, the nepheline-rich rock of Craigmont with corundum, seems to call for special mention and emphasis.

Craigmont (formerly Robillard mountain) is a well marked topographical feature rising abruptly from Campbells marsh (an expansion of the York river) and extending as far west as the post road between Combermere and Fort Stewart. It covers most of the first four lots in the eighteenth and nineteenth concessions of Raglan township, in the county of Renfrew, the line between these two concessions running along the southern slope of the mountain. According to the mean of several observations with two aneroid barometers, the mountain rises to a height of 500 feet above the dam at the old mill on the creek, which latter is ninety-five feet above Campbells marsh. This added to 931 feet, the height given by White[1] for the junction of the York and Madawaska rivers, gives 1,426 feet as the height of the top of Craigmont above mean sea-level.

The rock composing the mass of the mountain is a rather dark coloured hornblende-granitite-gneiss, evidently representative of the gneisses of the great Laurentian batholith.

[1] Altitudes in Canada, 1901, p. 199.

This is intimately associated with, but apparently older than a red syenite gneiss, distinguished mainly by an apparent absence of quartz, and a marked paucity of ferromagnesian material. In fact, quartz, except in the form of occasional secondary veins filling irregular fissures, is conspicuous by reason of its scarcity all over the hill. The reddish syenite passes into a grey syenite, also quartz free, the transition being apparent both in the direction of and across the foliation, consisting mainly of the failure of the red feldspar (orthoclase and microcline), and their replacement by plagioclase (oligoclase). Cutting across the foliation of these rocks are two sets of pegmatite dikes or veins. One is made up of red feldspar, chiefly orthoclase, with hornblende, quartz, calcite, etc., and is genetically connected with the Laurentian granitite-gneiss first mentioned. The other is made up almost wholly of microperthite, with more or less abundant corundum and other accessory minerals. (See pp. 241 and 326). Quartz is only very occasionally represented, and the rock is essentially a corundum-syenite-pegmatite. At certain places, chiefly towards the west end of the mountain, on lot 2, about twenty-five chains north of the line between concessions XVIII and XIX, the grey syenite passes directly into a nepheline syenite, considerable portions of which are an almost pure nepheline rock. Crystalline limestones occur as considerable inclusions in the gneissic rocks, while what are apparently portions of a comparatively large and continuous band are exposed in the neighbourhood of the old mill on the creek to the south of the mountain. The strike of the foliation of these rocks agrees very closely with the general trend of the mountain, or N. 75° E., with a prevailing southerly dip $< 10°$ 12°. Corundum occurs in the craigmontite as well as in the nepheline syenite (raglanite) and in the red and grey syenites, but is especially abundant in the red syenite-pegmatite. The corundum bearing rocks are confined to the southern slope of the mountain and apparently form a distinct layer of variable thickness overlying the barren gneisses of the Laurentian, and overlain by the crystalline limestone above mentioned. This fact has been recently definitely ascertained by boring, so that future extension of mining work will have to be carried on by quarrying along the strike instead of by deeper workings.

The nepheline syenite is composed chiefly of a salmon pink to flesh red nepheline, which is generally the most abundant consti-

tuent, a light grey almost white plagioclase (oligoclase), and very occasional scales and flakes of biotite. The nepheline where exposed shows the characteristic weathering, occurring in irregular sunken areas, with all the inequalities rounded off, leaving the white plagioclase in well marked angular relief. The corundum occurs in sharp, characteristic, often barrel-shaped hexagonal crystals, the longer axis of the abundantly distributed crystals lying at right angles to the foliation.

Two specimens, each containing corundum, were selected for examination, representing approximately the extreme phases of this rock. The thin sections show a rock made up of nepheline, oligoclase, muscovite, calcite, biotite, magnetite, and corundum. Some of the nepheline is comparatively fresh, but most of it has undergone more or less decomposition, the resultant products consisting of a brilliant polarizing aggregate of minute scales, chiefly of muscovite, developed along certain irregular lines and cracks. The plagioclase is likewise somewhat turbid from incipient alteration. Only occasional very small scales of biotite were noticed, and still more rarely small grains of magnetite. The corundum in the thin sections consists of irregular-shaped, apparently corroded individuals, embedded in plates and scales of muscovite.

An analysis of the nepheline-rich variety by Mr. M. F. Connor, B.Sc., of the Geological Survey, shows it to have the following composition:—

SiO_2	48·38
TiO_2	trace
Al_2O_3	30·54
Fe_2O_3	0·40
FeO	0·06
MnO	trace
CuO	trace
CaO	1·87
MgO	0·19
K_2O	3·70
Na_2O	13·94
P_2O_5	trace
CO_2	0·62
H_2O	0·50
	100·20

If the norm of this rock be calculated, it will be found to be as follows:—

Orthoclase	21·68
Albite	10·48
Anorthite	5·56
Nepheline	57·94
Corundum	1·63
Calcite	1·42
Hematite	·40
Fosterite	·35
	99·46
Water	·50
	99·96

This gives the rock the following position in the quantitative classification:—

Class I	Persalane.
Order 7	Tasmanare (near Ontarare.)
Rang 1	Langenase.
Sub-rang II	Craigmontose.

This is a new type for which we propose the name, Craigmontose (craigmontite).

The mode or actual mineralogical composition of the rock is somewhat different from the norm as given above:—

Nepheline	63·18
Oligoclase	29·66
Muscovite	4·39
Calcite	1·42
Corundum	·50
Biotite	[illegible]0
Magnetite	·[illegible]0
	99·75

An analysis of the associated nepheline syenite, which contained less nepheline and more plagioclase and corundum, by Mr. M. F. Connor, B.Sc., of the Geological Survey, shows it to have the following composition:—

Corundum	4·45
SiO_2	55·45
TiO_2	0·30
Al_2O_3	21·65
Fe_2O_3	0·81
FeO	0·49
MnO	0·01
CaO	3·65
MgO	0·13
K_2O	1·62
Na_2O	9·31
P_2O_5	0·01
CO_2	0·88
H_2O	1·64
	100·40

If the norm of this rock be calculated it will be as follows:

Orthoclase	9·45
Albite	56·59
Anorthite	12·51
Nepheline	11·93
Corundum	4·45
Calcite	1·98
Magnetite	·70
Ilmenite	·61
Hematite	·30
Fosterite	·21
	98·73
Water	1·64
	100·37

This gives the rock the following position in the quantitative classification:—

Class I	Persalane
Order 6	Russare near Tasmanare
Rang II	Viezzenase
Sub-rang V	Persodic

This is a new type for which we proposed the name, Raglanose (raglanite).

The mode or actual mineralogical composition of the rock is somewhat different from the norm the difference being represented chiefly in the grouping of the feldspar molecules, and in the modal presence of micas. The rock is actually composed of oligoclase nepheline, corundum (4·45 per cent), with small amounts of muscovite, biotite, calcite, magnetite, and apatite.

These somewhat abnormal and unusual types of rock are of especial interest and significance from the presence, and at times abundance of the corundum. The chemical analyses of both these types give very remarkable emphasis to the fact that these rocks conform very closely to the law formulated by Morozewicz from the observations of the behaviour of the cooling of magmas artificially produced. This law in brief recites that the development of corundum in any pure alumino-silicate magma is directly dependent on the ratio of the alumina to the sum of the other bases. An inspection of the chemical analyses, as mentioned above will show that the composition of these rocks correspond very closely to the general formula $R_2O, Al_2O_3, 2·6–4SiO_2$, with an abnormally small amount of magnesia and ferrous iron. Soda is very largely in excess amongst the alkalies, thus making it an extremely good solvent for alumina. It thus satisfies in every particular as a magma the several conditions laid down by Morozewicz, which require that not more than 0·50 per cent of MgO and FeO be contained in the magma, which if exceeded would tend to assist in the formation of spinel, or spinel and corundum.

The occurrence of the first mentioned type of nepheline syenite seems truly remarkable, for it furnishes, so far as known from natural exposures, a perfectly unique mineralogical association, with very abundant nepheline, and at the same time a scarcity of ferromagnesian minerals, and a small amount of corundum. The specimen represents a phase of this rock in which the alumina was only very slightly in excess of that required to satisfy the other constituents, this surplus amount crystallizing as free alumina in the form of small corundum crystals.

White Alkali Syenite.

This sub-division of these syenites is quite distinctly and certainly a differentiation product of the nepheline syenite, with this material difference, that nepheline is either altogether absent, or degraded to the position of an accessory or accidental consti-

tuent. It is pre-eminently a plagioclase rock, often occurring as interfoliated masses or bands with the ordinary type of nepheline syenite in which nepheline is an essential and usually abundant constituent. At other times it forms large and independent masses covering a large extent of country. It may therefore be regarded as a rock of intermediate type, marking a transition between the nepheline syenite and the red variety of the alkali-syenite, although genetically it would seem to be more closely related to the former than to the latter type.

The white or grey colour is dependent on the scarcity or otherwise of the bisilicate material. The constituent minerals are identical with those present in the nepheline syenite, with the exception that sodalite and cancrinite, always associated with the nepheline when present, do not occur. The other minerals, both essential and accessory, are common to both types, and as they have already been rather fully described, need only a passing mention in the present instance.

Plagioclase is the prevailing, and usually the only feldspar present. Albite, oligoclase, and andesine are the several species met with in the different outcrops examined. As in the case of the nepheline syenite, separate masses of this rock seem to be characterized by the presence of one or other of these species of plagioclase to the almost complete exclusion of the rest. The evidence furnished by the optical determination of the component grains, and corroborated by the separations undertaken with the heavy solution, is convincing that two or more of these species of plagioclase may be present, replacing to a small extent only the predominant type.

Plagioclase often makes up from 75 to 95 per cent of the whole rockmass, the remainder being divided between biotite, muscovite, calcite, magnetite, and occasionally corundum, scapolite, and nepheline. Some extreme phases of this rock are made up almost entirely of plagioclase, with little or no ferromagnesian or other minerals. When such rocks contain an excess of alumina which has crystallized out as corundum, they are very closely related, if not identical with the type plumasite, described by Lawson.[1]

[1] Bull. Dept. Geol. Univ. of California, vol. iii, No. 8, pp. 219-229.
It is to be noted that the feldspar in Lawson's plumasite is highly altered containing 1·7 p.c. of water. It has the specific gravity [illegible] extinction of oligoclase but the composition of andesine. The excess [illegible]lica found by Lawson in the rock was probably derived from the agate m[illegible] in which the material for analysis was ground. (See p. 328.)

The specimen selected for examination as typical of this variety was obtained from exposures on lot 12, concession XV of Dungannon. When collected it was considered a very fresh and unaltered as well as representative specimen of the nepheline syenite, which contained corundum in such abundance as to be considered an ore of this mineral. Nepheline syenite does occur at this locality, containing abundant corundum and nepheline in immediate association with one another, but the thin sections of the hand specimen selected for microscopical examination and chemical analysis show it to contain only very occasional small grains of nepheline. The specimen was purposely selected from material which had been recently removed by blasting, and the very freshness of the rock rendered it impossible to ascertain definitely the amount of nepheline present, the mineral in such case being indistinguishable, in the hand specimen, from the feldspar. The nepheline syenite at this locality is made up principally of nepheline plagioclase and biotite. In places scapolite is abundant in large individuals and patches of a yellowish colour. Occasional basic patches show the presence, and at times abundance of hornblende (hastingsite). The syenite is well foliated, the strike of this structure being in the direction of N. 25° E. The rock is considerably disturbed and cut through in various directions by dikes of flesh red pegmatite, composed principally of red feldspar (orthoclase and microperthite) and quartz, together with a little hornblende. In one or two places some imperfect crystals of this last mentioned mineral measured from four to six inches across.

These dikes are evidently differentiated forms of a red syenite, which occurs in considerable volume immediately to the southeast of these exposures, and is probably a somewhat more quartzose type of the normal red variety of alkali-syenite, which will be described later. Although there is usually a more or less definite line of separation between the red and grey types of syenite, the general relations of the two rocks offer much presumptive evidence for considering them as differentiated forms of the same magma, the red syenite being the latter in crystallization. At one outcrop, occurring at this locality, the normal type of medium grained grey syenite, made up almost wholly of plagioclase, passes by an abrupt, though quite perceptible transition into a coarse pegmatitic phase, made up almost entirely of the same feldspar. This, in turn, is gradually replaced along the course of the

same dike by a mixture made up of plagioclase, together with a considerable proportion of red feldspar (microperthite). Still farther along, and in the wider portions of the dike, the plagioclase is almost entirely replaced by the microperthite and a small proportion of quartz.

The corundum is by no means uniformly distributed through this rock, and large portions are completely barren of this mineral while certain rather ill-defined areas on the other hand contain a very high percentage. In outcrops exposed to the weather the corundum is very conspicuous, weathering out with pronounced relief from the surrounding matrix. It occurs for the most part in small imperfect crystals and grains, although occasional, characteristic barrel-shaped hexagonal crystals are several inches in length. In freshly broken rock the corundum is scarcely noticeable, except it assumes the prevailing and characteristic bluish colour. Many of the individuals have exceedingly rough and porous outlines, due no doubt to the removal of much of the associated micaceous material. Under the microscope the thin section shows the rock to be made up largely of plagioclase. The symmetrical extinction angles of the albite lamellæ are those characteristic of andesine. This optical determination was subsequently confirmed by its separation with the heavy solution, and chemical analysis of the material thus obtained. Corundum is the next most important mineral constituent, and is often so abundant as to characterize the rock. Some of the individuals show rather perfect crystallographic development, but for the most part the mineral occurs in imperfect crystals or irregular grains. Much of the corundum shows the peculiar parting planes or pseudo-cleavage, especially those parallel to the faces of the rhombohedron and the base, both of which are perfectly developed. The colour is not uniformly distributed, but indefinite patches of white, blue, and brown are often noticed. Most of the mineral has quite a distinct and often pronounced sapphire blue colour. Occasional fragments show a comparatively deep brownish colour, arranged in parallel bands with well defined straight lines as boundaries. These brownish streaks alternate with others, which are nearly if not quite colourless under the microscope. Some of the individuals have little or none of the muscovite corona surrounding them, while others, manifestly imperfect and much corroded, have quite a wide mantle of this so-called alteration product

Fig. 1. Microphotograph of corundum, showing plates of parting; with andesine, biotite, and muscovite, lot 12, concession XX Dungannon township. Magnified 40 diameters.

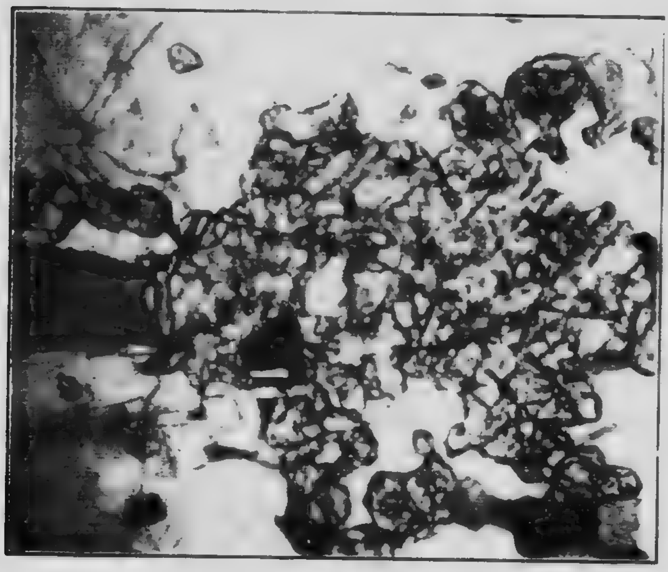


Fig. 2. Microphotograph of corundum; with muscovite, biotite, and plagioclase, lot 2, concession II, Monteagle township. Magnified 40 diameters.

surrounding them. (See Plates LIV and LXII). Corundum is quite plentiful in the thin sections examined. On account of its much greater resistance during the grinding operation necessary in the making of the thin sections, it possesses an abnormally high index of refraction, and consequently much greater relief, as well as double refraction. Scapolite is also present, usually in comparatively small amount, the larger individuals occupying the interspaces between the feldspars, with little to suggest its derivation from them. Some smaller grains enclosed in the feldspar may represent secondary action. The mineral shows the characteristic cleavages, with parallel extinction and strong double refraction. Biotite is present in occasional and comparatively small plates, showing very marked pleochroism from yellowish to very dark greenish brown, and very pronounced absorption of the rays vibrating parallel to the cleavages. Muscovite occurs, both intergrown with the biotite, and as shells or mantles of variable width surrounding most of the corundum individuals. It is regarded as a primary constituent, formed as already explained at a time immediately preceding the complete solidification of the magma.

Occasional grains and imperfect crystals of magnetite, and a still smaller amount of calcite, complete the list of minerals noticed in the thin sections under the microscope.

An analysis of this rock was made by Prof. Norton-Evans, with the following results, under I.

	I	II		
SiO_2	49·56	58·32	97.	
Al_2O_3	33·70	23·80	·233	
Fe_2O_3	·93	1·09	·006	
FeO	1·42	1·67	·023	
CaO	5·89	6·67	·119	·280
MgO	·97	1·14	·029	
K_2O	1·23	1·44	·015	
Na_2O	4·95	5·83	·094	
CO_2	·17			
H_2O	·84			
	99·66			

Deducting the excess of alumina present as corundum, which was determined by trial, neglecting the loss on ignition (H_2O) and deducting the amount of lime (CaO) necessary to form calcite with the CO_2 in the rock, the results given under II are obtained. This is the composition of the residual or alumina saturated magma.

Morozewicz[1] has shown by direct experiment that in supersaturated alumino-silicate magmas, whose general composition is RO, m Al_2O_3, n SiO_2 (where R = K_2, Na_2, or Ca; and n > 2), the whole of the excess of alumina separates out (1) as corundum if no considerable amount of MgO or FeO is present and if n is less than 6; (2) as sillimanite and corundum if n is greater than 6; (3) when the magma is rich in magnesia, as spinel or spinel and corundum if n is less than 6; (4) as cordierite or cordierite with one or more of the other minerals if n is greater than 6. The absence of corundum in the nepheline syenites of India is explained by Holland as due to the fact that this rock, as shown by analysis, contains too much MgO and FeO, and he refers to the abundance of iron-magnesia minerals in the nepheline syenite, and the scarcity of such minerals in the corundum syenite, as amply accounting for the abundance of free alumina in the latter and its absence in the former. A similar low content of iron and magnesia is noticeable in the Canadian corundum syenites, and, together with the high percentage of alumina in the magma, probably explains the development of corundum in them.

The ratios of the molecular values of ($CaO + K_2O + Na_2O$): Al_2O_3: SiO_2 in the rock at present under consideration are as follows:

·228	:·233	:·972
1	: 1	:4·2

The ratio of K_2O : Na_2O = 1:6 and alumina to the bases, is a little in excess of 1:1. As a magma for the solution of alumina and its complete separation as corundum on crystallization, it is therefore in perfect agreement with Morozewicz's law. Of the alkalis, soda largely predominates, this lending the necessary assistance in the solution of the alumina. There is an excess of ferrous iron and magnesia, above what has been thought permissible (0·05 per cent) by Morozewicz's law, but these amounts have been necessary to assist in the formation of the comparatively small

[1] Tscher. Mitt. Band xviii (1898), pp. 1-90 and 105-240.

quantities of magnetite and biotite present in the rock. It is therefore evident that Morozewicz's law, as remarked by Holland[1], does not represent the whole truth, for it might be expected, with this excess of ferrous iron and magnesia, that spinel would be formed in addition to the corundum. This mineral was, however, not seen in the thin sections, nor was it found in any of the outcrops in the vicinity where this rock specimen was collected.

The norm of the rock is as follows:

Quartz	1·26
Orthoclase	7·23
Albite	41·92
Anorthite	29·19
Corundum	13·46
Hypersthene	4·12
Magnetite	1·39
Calcite	·37
	98·94
Water	·84
	99·78

In calculating this norm from the chemical analysis, there was, as shown, an excess of 1·26 per cent of silica above that required and which appears in the norm as quartz. By direct experiment it was subsequently shown that most, if not all of this silica was derived from the agate mortar and pestle which was used in grinding the sample. There is no free silica or quartz shown in the thin sections, nor was any of this mineral found in the separation of the rock by means of the heavy solution.

The mode or actual mineralogical composition cannot be calculated with certainty on account of the presence of the two micas and the scapolite, the latter having about the same formula as the feldspar. The corundum, magnetite, and calcite are normative, that is, they are present essentially in the percentages given in the norm. From an inspection of the slides the following would seem to be a very close approximation to the mineralogical composition of the rock:

[1] Mem. Geol. Surv. Ind., vol. xxx, part 3 (1901), p. 208.

Andesine (near Ab_3An_2)	72·00
Nepheline	3·00
Scapolite	2·00
Corundum (by trial)	13·24
Biotite	5·00
Muscovite	3·00
Magnetite	1·39
Calcite	·37
	100·00

Owing to the large percentage of corundum present, the rock is a very peculiar and unusual one, and fills as yet an unrepresented sub-class, order, rang, and sub-rang in the quantitative classification. We accordingly propose the following names for the new rang and sub-rang, and the name Dungannonite for the rock itself:—

Class I	Persalane.
Sub-class II (section I)	Dosalane.
Order 5	Indare.[1]
Rang 3	Dungannonase.
Sub-rang 4	Dungannonose.

An analysis of the andesine occurring in the rock was made by Mr. M. F. Connor, B.Sc. This is given under I. The material for the analysis was obtained by separating the feldspar with Thoulet's solution, but was somewhat impure, owing mainly to the admixture of a small amount of biotite. This accounts for the iron, potash, and magnesia found in the analysis. Neglecting these, the composition corresponds rather closely to that of an andesine with the formula Ab_3An_2, with 0·96 per cent too little of silica and 1·68 per cent too little of lime. The specific gravity for such a mixture should be 2·68, while that of the andesine separated from the rock was 2·668, this slight decrease in weight being no doubt due to the unusually low lime. For purposes of comparison, the theoretical composition of andesine corresponding with the generally accepted formula for this species of plagioclase with the ratio of the soda to the lime of 1:1 (Ab_2An_1), is given under II, while under III is quoted the composition of andesine, made up of a mixture of albite and anorthite in the ratio of 3:2.

[1] H. S. Washington. Chemical Analysis of Igneous Rocks. Prof. Paper No. 14, p. 217, U.S. Geol. Survey, 1903.

	I	II	III
SiO_2	57·15	59·84	58·11
Al_2O_3	26·74	25·46	26·62
Fe_2O_3			
FeO	0·25		
CaO	6·66	6·97	8·34
MgO	0·59		
MnO	trace		
K_2O	0·38		
Na_2O	6·83	7·73	6·93
H_2O	0·90		
	99·50	100·90	100·00
Specific gravity	2·668	2·671	2·680

An analysis of the blue corundum which occurs associated with this rock was made by Mr. M. F. Connor, B.Sc., with the following results:

SiO_2	none.
Al_2O_3 (diff.)	96·90
Fe_2O_3 + FeO	0·76
CaO	0·46
MgO	1·00
H_2O	0·88

Red Alkali Syenite.

Associated with the white or grey variety of the alkali-syenite, as well as with the nepheline syenite, and passing into these sometimes by an abrupt, though usually by a gradual transition, are certain highly feldspathic rocks, often occurring as very extensive and independent masses, which are distinguished in the field mainly by their reddish colour and the marked scarcity or absence of quartz. They differ from the white and grey varieties in that orthoclase, microcline, and microperthite (the latter confined mostly to the pegmatitic phases), are quite abundant, and sometimes the predominant feldspars. Plagioclase is also very plentiful, sometimes equalling in amount if not exceeding the potash feldspars. A comparatively large area representative of this variety of syenite occurs intimately associated with the nepheline syenite near the York river, and was referred to in the first published descriptions as "a reddish biotite granite resembling aplite in appearance."[1] This rock is exposed on both sides of the York river, extending from the eleventh to the fifteenth concession. Nepheline syenite occurs

[1] Am. Journ. Sc., vol. xlviii, 1894, p. 11.

on both sides of this batholith, and if the outcrops of this rock could be traced and found continuous would doubtless form an association closely analogous to that described as occurring in the township of Monmouth. The rock is essentially a quartz-mica-syenite, made up almost wholly of orthoclase, microcline, albite, quartz, biotite, and in places hornblende. The biotite is in very small and exceedingly irregular or ragged scales, with strongly marked pleochroism and absorption. This brownish biotite has a distinct greenish tinge. The various cracks and fissures are filled with reddish brown iron oxide, which also stains the orthoclase and microcline. The rock is younger than the nepheline syenite, which it sometimes intersects, and decidedly later than the surrounding crystalline limestone. Its association with the nepheline syenite, however, is strongly suggestive that both are the products of the one magma, the red syenite being the later product of solidification.

A similar type of rock prevails along the southern slope of the hill at Craigmont, in Raglan township. Its mode of occurrence, association, and relations with the older Laurentian gneisses, as well as with the nepheline syenite, have already been described. This reddish or pinkish rock frequently contains bands of a dark coloured, highly micaceous rock, which represent deformed and altered dikes of basic composition. In places, masses and patches of almost pure hornblende occur. A specimen of the brownish red highly feldspathic variety of the rock, with a distinct streaked appearance, owing to small ragged scales of biotite with more or less parallel arrangement, was analyzed by Mr. M. F. Connor, B.Sc., with the following results:

SiO_2	56·05
TiO_2	0·47
Al_2O_3	17·02
Fe_2O_3	9·10
FeO	4·20
MnO	0·08
MgO	0·12
CaO	0·72
K_2O	5·12
Na_2O	6·10
P_2O_5	0·04
H_2O	0·36
	99·38

The ratio of	$(CaO+K_2O+Na_2O)$	: Al_2O_3	: SiO_2
	·162	: ·165	: ·934
	1	: 1	: 5·7

If the norm of this rock be calculated it will be found to be as follows:

Orthoclase	30·02
Albite	51·35
Anorthite	3·62
Corundum	·29
Magnetite	12·30
Ilmenite	·91
Hematite	·64
Olivine	·31
	99·35
Phosphoric acid	·04
Water	·36
	99·75
Deficit in silica	·27
	99·48

The position of the rock in the quantitative classification is accordingly as follows:

Class II	Dosalane.
Order V	Germanare.
Rang I	Umptekase.
Sub-rang IV	Umptekose.

The mode of the rock, that is to say, its actual mineralogical composition, does not differ essentially from the norm, the rock being made up of orthoclase, microcline, albite (about Ab_7An_1), and magnetite, with a little biotite, which latter mineral in the norm is represented by other mineral combinations. No quartz is present, ·27 per cent of additional silica being required to satisfy the feldspars in the norm.

The rock which contains the largest and most abundant crystals and masses of corundum at Craigmont, and thus the richest ore of this mineral, is the corundum-syenite-pegmatite, which occurs in the form of dikes or veins, varying from six to eighteen feet in width. (See p. 311). These dikes intersect the medium

grained or normal type of red syenite just described, which also contains corundum, although in less abundance and in smaller individuals. (See Plate LXII). They are made up almost wholly of a deep flesh red to very pale salmon-pink feldspar, which in thin section under the microscope is seen to be an irregular intergrowth of orthoclase and albite, the former feldspar being the more abundant. Associated with this microperthite as accessory constituents, locally and usually in small amount, are biotite, muscovite, scapolite, calcite, magnetite, hematite (micaceous iron ore), molybdenite, pyrite, pyrrhotite, chalcopyrite, chrysoberyl, spinel, and quartz. Although quartz and corundum are commonly supposed to be mutually exclusive, specimens have been found containing these two minerals in small amount.

Mr. M. F. Connor, B.Sc., has made an analysis of this corundum-syenite-pegmatite from Craigmont, Ont., the results adjusted to a basis of 100 being given under I. For purposes of comparison the analyses of the corundum-syenite-pegmatite, and of the corundum-syenite from Nikolskaja Ssopka in the Urals, Russia, are included under II and III. (Tschermak's Min. und petr. Mittheil., XVIII, 1898, p. 219). Under I (a) is given the analysis of I, omitting the corundum and adjusting it to a basis of 100. Under II (a) and III (a) are similarly included analyses of II and III, in which the corundum is neglected and the remaining constituents recalculated to a basis of 100. Under IV is an analysis of the separated microperthite from the corundum-syenite-pegmatite of Craigmont, Ont. Under V is an analysis of a similar feldspar of the corundum-syenite-pegmatite from Sivamalai, India.[1]

	I	II	III	Ia	IIa.	IIIa.	IV	V
Corundum	34·62	35·40	18·55					
SiO_2	40·53	40·06	52·34	62·30	62·71	64·65	63·43	63·26
Al_2O_3	13·62	13·65	16·05	20·93	21·37	19·83	20·78	21·87
Fe_2O_3	0·19	0·35	0·45	0·29	0·55	0·56	0·29	0·22
FeO	0·04	....	....	0·06	....	....	....	
CaO	0·67	0·30	0·20	1·02	0·47	0·25	1·00	0·21
MgO	....	0·15	0·16	....	0·23	0·19	0·07	....
K_2O	5·92	5·20	6·58	9·10	8·14	8·14	8·00	3·09
Na_2O	3·40	3·71	4·77	5·23	5·81	5·89	5·20	10·25
H_2O	1·01	0·46	0·40	1·07	0·72	0·49	1·00	0·78
	100·00	99·28	99·50	100·00	100·00	100·00	99·79	99·68

[1] Mem. Geo. Surv. India, vol. XXX, part 3, 1901, p. 202

An examination of the above analyses will show at a glance the remarkable similarity in chemical composition of these corundum-bearing rocks, occurring at such widely separated localities in Canada, Russia, and India. The specimens of the Canadian and Russian occurrences are practically identical. No analysis of the corundum-syenite from India is available, but the analysis of the feldspar, which is very closely analogous in composition to that of the rock with the corundum deducted is also very similar, the only substantial difference being in the relative amounts of soda and potash present. Taking into consideration the molecular values of soda and potash, the ratio of the soda to the potash in the Indian occurrence is 5 : 1, while in the Canadian and Russian occurrences the soda is only slightly in excess, and in the separated feldspar is practically the same.

The corundum-syenite-pegmatites of Craigmont, and of Nikolskaja Ssopka, have the following position in the quantitative classification:

Class I.
Sub-class II.
Section I.
Order V. . . . . Indare.
Rang I. . . . . Uralase.
Sub-rang III. . . . . Uralose.

The following are the molecular ratios of the corundum syenite (freed from corundum) as above:

	$(CaO + K_2O + Na_2O)$	Al_2O_3	SiO_2	
Analysis I(a)	1	1	5·2	Ontario
Analysis II(a)	1	1·1	5·5	Russia
Analysis III(a)	1	1·1	5·9	Russia
Analysis V	1	1	5·2	India

The method used for the determination of percentage of corundum in these rocks is as follows. After first pulverizing the sample by the use of a hard faced steel hammer (say 3 lb. hammer) on a hardened steel surface of a plate 5″ x 5″ x 1″, and then grinding to a fine powder in a small agate mortar, the sample is weighed (1 gramme), and ignited for ten minutes in a platinum crucible,

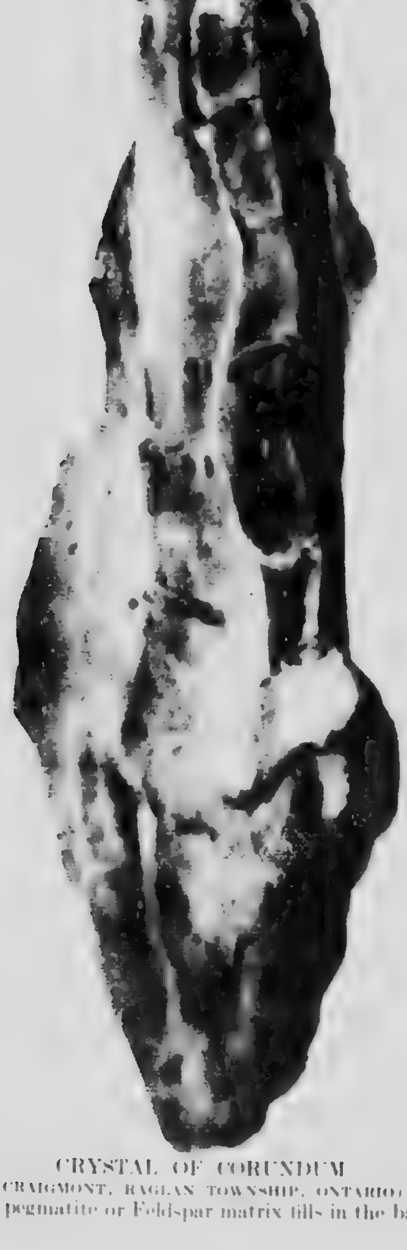
and placed in a platinum evaporating dish (say 200 c.c.). Water is added, also about 10 c.c. of hydrofluoric acid c.p. and 5 c.c. of sulphuric acid; place on the water bath and evaporate till the rock is thoroughly decomposed, and all silica evaporated from the solution, dilute, add a little hydrochloric acid if necessary to bring sulphates into solution: digest, filter, wash, and ignite; weigh as corundum. After some little practice the operator can judge as to the solution of the rock being thorough, etc. Fine grinding of the sample is required, although not too fine. In an accurate analysis, it must be remembered that the corundum wears the agate in the process of grinding, and the silica thus worn from the mortar and pestle, becomes incorporated with the rock sample. This can be accurately allowed for by weighing the little mortar and pestle before and after the operation of grinding, and distributing the loss over the total number of grammes of sample ground in the mortar.

Potassium bisulphate is required for the solution of corundum, if it is found necessary to analyze the corundum itself.

In the estimation of the corundum there is a slight attack of the corundum by the hydrofluoric and sulphuric acids. This is best determined by the operator himself by taking selected, pure crystals of corundum, and making an analysis of the material before and after treatment, (bearing in mind as above mentioned, correction for silica taken up from the agate mortar.)

In the analysis of the corundum itself, two acetate separations with an ammonia precipitation to separate any alumina from the filtrates will give good results. The lime and magnesia may then be determined. If it suits the purpose for which the analysis is made, the alumina may be approximately determined by subtraction of water, iron oxide, lime and magnesia, and silica percentages from 100, and thus avoiding a long washing of the extremely bulky alumina precipitate.

Analyses of the brown corundum and of the magnetite which are present in the corundum-syenite-pegmatite of Craigmont, have been made by Mr. M. F. Connor, B.Sc. These are given below under I and II respectively. The material in both cases was selected as free as possible from impurities or alteration products:—



CRYSTAL OF CORUNDUM
(CRAIGMONT, RAGLAN TOWNSHIP, ONTARIO)
The syenite pegmatite or Feldspar matrix fills in the basal cracks.

	I		II
SiO_2	none	Silica and Silicates	1·40
Al_2O_3 (diff)	95·58	Fe_3O_4	65·04
Fe_2O_3	2·10	FeO	30·60
CaO	0·48	TiO_2	2·50
MgO	1·00	H_2O	0·57
H_2O	0·84		
	100·00		100·11

Specific gravity (average four determinations) 3·95

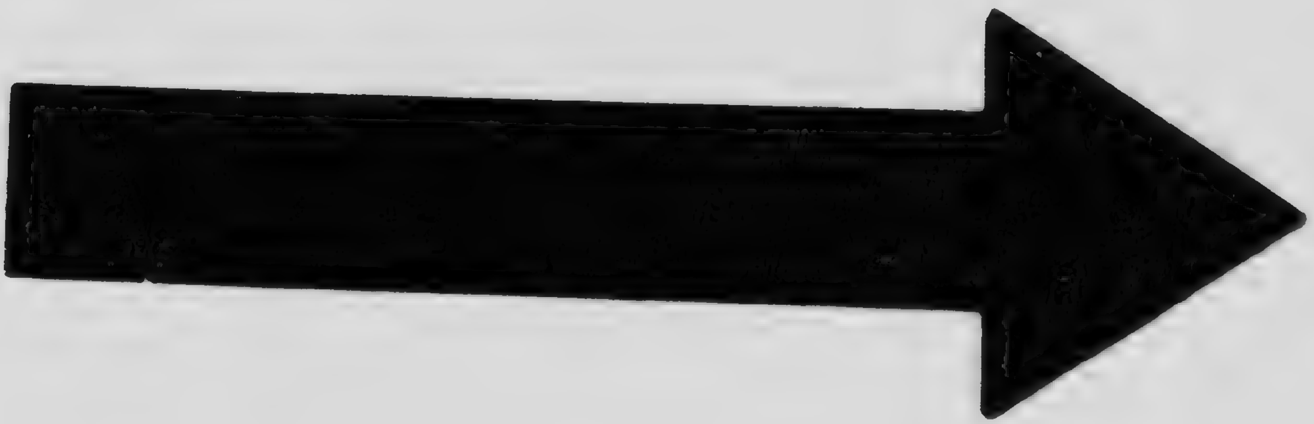
The occurrence of corundum, in association with perfectly fresh and unaltered minerals, in rocks of undoubtedly igneous composition and behaviour, at once removes all doubt as to the pyrogenesis of the mineral, showing clearly its development as one of the first products of the crystallization of a magma, supersaturated with alumina and very poor in ferromagnesian minerals. The chemical analyses, as already furnished, are in remarkably close agreement with the law formulated by Morozewicz, as a result of direct experiment with fused and cooling magmas, not only as to the conditions essential to the solution of alumina, in such alumino-silicate magmas, but also the subsequent separation of all the excess as corundum, on their crystallization. (See Plate LXIII.)

GENERAL STATEMENT CONCERNING THE NEPHELINE SYENITES OF THE AREA.

1. The nepheline and associated alkali syenites of this district present one of the most extensive developments of these rocks in the world. They form part of the pre-Cambrian complex of the great Canadian shield, and occur along the borders of the batholiths of Laurentian granite-gneisses where these intrude the crystalline limestones of the Grenville series.

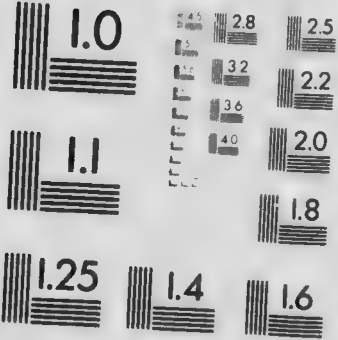
2. They differ from most occurrences of these rocks which have been described from other parts of the world in that they have not the massive character of ordinary intrusions, but possess a distinct gneissic or foliated structure.

This parallel structure which they usually display is combined with a *schlieren* or streaked structure, which in small



MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No. 2



APPLIED IMAGE Inc

exposures gives rise to a banded appearance, the several bands differing in the relative proportion of constituents present. The foliation is not such as would be produced by the direct crushing of a massive rock. Cataclastic structure is seen only in one or two places, and the rock very rarely shows any distinct evidence of pressure. The arrangement of the component minerals, with their longer axes in the same direction, produces the foliation, while their variation in amount from band to band serves to emphasize it. The rock is, as a general rule, poor in iron-magnesia constituents, and its appearance on the weathered surface so closely represents that of the crystalline limestones of the Laurentian, which are often more or less impure from the development of secondary silicates in streaks and bands through them, that it is often impossible to tell the two rocks apart at a distance of a few yards.

3. The nepheline syenite magma throughout the area is one which is relatively very rich in soda. The plagioclase present is in most cases albite, but sometimes also andesine, and these feldspars preponderate largely over the orthoclase, and are frequently the only feldspars which the rock contains. The rock furthermore differs from the great majority of other occurrences, in that instead of augite, which usually occurs in these rocks, it contains either biotite (lepidomelane) or hornblende as the iron-magnesia constituent, augite being seldom present, and when it occurs, being always in very subordinate amount. In this respect it resembles the Indian occurrences, as well as those at Miass Russia, in which biotite is the prevailing dark constituent.

4. The nepheline syenites of this area show a fine series of differentiation products. These range from granite at the acid end of the series, through alkali syenites rich in soda, corundum syenites and allied rocks, and nepheline syenites, to nepheline rocks—and with increase in the quantity of iron-magnesia constituents to varieties having the composition of essexites, and even to more basic forms.

As a result of this abundance of soda in the magma is the frequent occurrence of varieties of the nepheline syenite which are extremely rich in nepheline, and which, by the disappearance of the feldspar, pass over into rocks which are composed almost exclusively of nepheline and iron-magnesia constituents. These

rocks are closely allied to the urtite[1] described by Ramsay from Finland, but contain hastingsite instead of aegerine as the prevailing dark constituent, and when the norm is calculated, are found to be relatively richer in the salic components, so that they fall into class I (Persalane) of the quantitative system, while the typical urtite belongs to Class II (Dosalane). These rocks thus constitute a new group, the type whose analysis is given on page 333, belonging to a new rang, which has been called Monmouthose of the order Ontarare. It is proposed to call this rock monmouthite.

In the terminology of the quantitative classification, the various differentiation products which have been analyzed are embraced by rangs 1, 2, and 3 of orders 4, 5, 6, 7, and 8 of the persalanes and dosalanes (sub-class I), with the exception of one of the new types which is a dosalone. A somewhat similar, though less extreme differentiation of an alkali-rich mag , has been described by Teall[2] in the district around Lake Borolan, concerning which he writes: "The facts above described clearly prove that we have in the plutonic complex of Lake Borolan a connected group of rocks formed by the consolidation of alkaline magmas rich in soda . . . . . the evidence available suggests that the quartz-syenites shade into the quartzless syenites, and these again into the nepheline syenites."

5. All phases of this magma were in certain localities supersaturated with alumina, which, when the magma was low in MgO and FeO, crystallized out as corundum, giving rise to several new rock types, three of which, Raglanite, Craigmontite, and Dungannonite are described.

The development of corundum from these magmas follows the law established experimentally by Morozewicz in his researches on artificial molten magmas.

6. Another striking feature presented by the nepheline syenites of the district covered by this paper, is the frequent appearance of very coarse-grained or pegmatitic developments of the rock. The constituent minerals are in many places a foot in diameter, while on the York branch of the Madawaska river,

[1] Ramsay, W.—Das Nephelinsyenitgebiet auf der Halbinsel Kola-Fennia. 15. 2, Helsingfors, 1899. p. 22.

[2] Teall, J. J. H.—Nepheline Syenite and its associates in the northwest of Scotland. Geol. Mag., Sept., 1900. p. 390.

in the township of Dungannon, where this stream is crossed by the road running east from Bancroft, the rock contains individuals of nepheline two and a half feet in diameter, while masses of pure nepheline a yard in diameter are found in the nepheline-syenite-pegmatite on lot 30, concession VI, of the township of Glamorgan. These pegmatitic developments in some cases have the form of dikes cutting the normal nepheline syenite, or some other rock, but elsewhere they are very coarse-grained masses or *flammen* in the finer grained nepheline syenite, apparently of the nature of contemporaneous veins, and correspond to the developments of pegmatite so often found in connexion with granite.

7. The nepheline syenite occurs almost invariably along the border of the granite intrusions where these are intruded through the limestone. When the actual contact of the nepheline syenite and limestone can be seen, masses of the limestone, great and small, are found scattered through the nepheline syenite along the contact. These masses are in course of replacement by the magma, and at a distance from the contact are seen to be greatly reduced in size and often disintegrated. Still further from the contact they are represented by irregularly rounded grains of calcite lying between the perfectly fresh individuals of the several constituent minerals of the nepheline syenite, or in some cases actually as inclusions in these minerals.

For convenience of reference, the twelve analyses of the nepheline and alkali syenites of this region which have been included in this report are tabulated below. This table includes the analyses of the four new rock types already described.

TABLE OF ANALYSES OF NEPHELINE AND ALKALI SYENITE FROM CENTRAL ONTARIO.

	Syenite, (Phlegrose) Monmouth, Con VIII, Lot 1?	Nepheline Syenite (Essexyose) Monmouth, Con. IX, Lot 16.	Nepheline Syenite, (Essexose) Monmouth, Con. VIII, Lot 11.	Nepheline Syenite, (Vulturose) Monmouth, Con. VIII, Lot 11.	Monmouthite, (Monmouthose) Monmouth, Con. VIII Lot 10	Alkali Syenite, (Miaskose) Methuen, Con. X, Lot 13-14.	Alkali Syenite, (Kallerud'ose) Methuen, Con. X, Lot 13-14.
SiO_2	64.15	51.58	43.67	42.72	39.74	59.68	65.89
TiO_2		.35	.78	.38	.13	none	none
Al_2O_3	19.04	19.40	20.91	25.08	30.59	23.48	19.73
Fe_2O_3	1.02	4.26	3.54	2.00	.44	.59	2.03
FeO	.93	5.25	8.01	4.36	2.19	.37	.75
MnO	.16	.20	.05	.16	.03	none	Trace
CaO	1.37	3.64	7.37	6.92	5.75	.26	.46
MgO	.37	.19	1.46	.97	.60	.21	.27
K_2O	7.10	4.23	2.25	2.69	3.88	4.68	3.95
Na_2O	5.37	7.49	6.73	11.02	13.25	9.52	6.59
P_2O_5	.10	.15	.11	.19	(A)	none	none
CO_2	.70	1.53	2.37	2.99	2.17	.04	.44
H_2O	.27	1.02	2.52	.88	1.00	.66	.34
	100.38	99.59	99.77	100.36	99.86 (x)	99.49	100.45

	Craignontite with Corundum (Craignontose) Raglan, Craignont.	Raglanite, with? Corundum. (Raglandose), Raglan, Craignont.	Dungannonite with Corundum (Dungannonose) Dungannon, Con. XV, Lot 12	Alkali Syenite with Corundum (Umptekose) Raglan, Craignont.	Syenite Pegmatite with Corundum. Raglan, Craignont.
SiO_2	48.38	55.45	49.56	56.05	40.53
TiO_2	Trace	.30		.47	
Al_2O_3	30.54	21.65*	33.70	17.02	13.62(°)
Fe_2O_3	.40	.81	.93	9.10	.19
FeO	.06	.49	1.42	4.20	.04
MnO	Trace (○)	.01		.08	
CaO	1.87	3.65	5.89	.72	.67
MgO	.19	.13	.97	.12	
K_2O	3.70	4.62	1.23	5.12	5.92
Na_2O	13.94	9.31	4.95	6.10	3.40
P_2O_5	Trace	.01		.01	
CO_2	.62	.88	.17	.	1.01
H_2O	.50	1.64	.84	.36	
	100.20 (x)	100.40 (x)	99.66 (x)	99.38	100.00

(A) SO_3 trace, Cl .02, S .07 (x) New type. (○) Cu trace *There must be added 4.45 per cent of corundum which was determined separately (°) There must be added 34.62 per cent of corundum which was determined separately.

ACID VOLCANIC ROCKS.

As will be seen from a glance at the Bancroft sheet, there is a large development of acid volcanic rocks in the township of Lake, extending from this township in a northerly direction into the adjacent township of Wollaston. There are three areas of these rocks, which partially surround and are probably genetically connected with what is probably a volcanic centre which is now occupied by the granite of Copeway lake.

The more southerly of these three areas displays these volcanic rocks in their less altered and most typical form. They are well exposed along the southern shore of Burnt lake, in concession VII of the township of Lake, as well as on a high rocky ridge which runs through the length of lot 8, concession V, and extends half way across the same lot on concession IV. The deeply indented shores of Burnt lake show in a most pronounced manner the influence of the strike of the rocks in a district of this kind upon the development of the topography. The strike of the amphibolites which are here associated with the acid volcanic rocks, as well as the indistinct foliation of these rocks themselves, strikes in a direction N. 40° E. and determines the whole shape of the lake, as well as the configuration of its bays and promontories. The contact of the volcanic rocks under consideration with the series of amphibolites, which present several varieties in kind, passes through the length of the lake, while the waters of the lake, which are discharged by Otter creek, which flows out of the southwestern extremity, here descend as a great waterfall over a high cliff of these volcanic rocks.

The rock at this fall, lot 17, concession VI, consists of a pink felsite, too fine in grain to be resolved by the naked eye, through which are scattered abundantly small phenocrysts of a pale pink feldspar. The rock is uniform in character over large exposures, although the phenocrysts are more abundant in some places than in others. It possesses a certain fissility, owing to the development of a little sericite or muscovite in one plane. Under the microscope the rock is seen to belong undoubtedly to the volcanic series. The porphyritic structure is shown in a striking manner (see Plate

Microphotograph of pre-Cambrian rhyolite. Falls at Burnt lake, lot 17, concession VI, township of Lake. Between crossed nicols. Magnified 25 diameters.

LXIV), the phenocrysts being exclusively feldspar, some of them orthoclase, but most of them microperthite. They all have good crystalline forms, and show no signs of crushing, although in one or two cases the phenocryst seems to have been broken. The groundmass is cryptocrystalline, presenting an appearance of flow structure, with a tendency of the phenocrysts to align themselves in the direction of the flow. The flow structure is marked by the presence of finer and coarser grained curving streaks in the groundmass. This structure is emphasized by the occurrence of minute strings of grains of black iron ore, and of little shreds of muscovite which have been developed in the line of flow. The structure is very typical and distinct. The groundmass between crossed nicols is seen to contain a certain amount of quartz. Here and there through the rock little areas or lines of more coarsely crystalline material are seen. These apparently have the same composition as the groundmass, but are prophetic of the coarser grained development which overtakes these rocks under progressive metamorphism. The rock contains no femic constituents other than the occasional little strings of iron ore, and the secondary muscovite.

The rock having identically the same character is exposed about the northeastern extremity of Burnt lake, and also forms the whole south shore of the lake, although along this stretch of shore it is poorer in phenocrysts than at either end of the lake. It also contains little flakes of biotite in addition to the muscovite, and shows a more marked tendency to the development of the coarser secondary crystallization to which reference h[illegible] made above.

[illegible] outhwestern extremity of this mass, on concessions IV [illegible] rock again presents an appearance very closely re[illegible] hat at Burnt lake. In some places here it is filled with phenocrysts, and shows excellent flow structure but elsewhere the phenocrysts are entirely absent, and the rock becomes a splintery felsite, which presents in a most marked manner the appearance of a devitrified glass. When examined under the microscope the groundmass of the rock here is seen to contain numerous minute biotite individuals which give to it a dark grey color.

The second area of these felsites runs parallel to that just described, and lies on an average about one mile farther north. It is associated along its southwestern extremity with the con-

glomerates described on page 47, of which it also forms most of the pebbles. The rock is a pinkish cryptocrystalline felsite, with occasional narrow streaks darker in colour running through it and giving to it a certain appearance of foliation or bedding. Under the microscope these felsites are seen to closely resemble those of the Burnt lake band, but they rarely show phenocrysts. These are present, however, in some cases, but can be seen to have been partly broken down by movements in the rock which gives to them the appearance of fading away into the groundmass. In addition to the minute individuals of iron ore and muscovite, they generally hold a small amount of biotite. The quartz in the little coarser grained aggregates which occur here and there through the rock shows undulatory extinction, as if it had been twisted by the action of great pressure. In addition to the muscovite, which occurs very sparingly in little strings through the rock, an occasional rather large skeleton crystal of this mineral can be seen to be developing in the quartz-feldspar mosaic.

In order to ascertain whether this felsite was identical in character with that of the Burnt lake band, and also with the view of ascertaining the relative proportion of quartz and feldspar in the rocks, a typical specimen from lot 19, concession V of Lake, as well as a typical specimen from lot 17, concession VI, were submitted to a partial chemical analysis, the silica, potash, and soda being determined. The percentage results are as follows:

	Felsite, lot 19, con. V, Lake	Felsite, lot 17, con. VI, Lake
SiO_2	63·94	71·28
K_2O	5·24	5·32
Na_2O	6·36	5·42

If these values be calculated out, they yield the following amounts of orthoclase, albite, and quartz respectively:

	Felsite, lot 19, con. V, Lake	Felsite, lot 17, con. VI, Lake
Orthoclase	30·6 p.c.	31·2 p.c.
Albite	54·0 p.c.	45·6 p.c.
Quartz	7·1 p.c.	19·8 p.c.
	91·7 p.c.	96·6 p.c.

The lower total in the case of the first of these rocks shows that there are certain other constituents present in considerable amount. These are the biotite and magnetite mentioned in the description of the rock. In both cases the plagioclase is probably not a pure albite, but contains a certain admixture of the anorthite molecule. This would lead to a diminution in the amount of quartz which has been calculated as present in the rock. The partial analysis shows that the rock from lot 17, concession VI, contains a considerable amount of free quartz, while that from lot 19, concession V, contains little. The analysis also shows the same preponderance of soda over potash—of plagioclase over orthoclase—which has already been referred to in the case of all the granite-gneiss forming the batholiths in this area.

Both rocks may be classed as Orthophyres.

The third area of these felsites lies in the northern part of the township of Lake, and passes over into the township of Wollaston, forming a wide band, which may be said to stretch from Lake Tangamong to the Ridge settlement. The rock in this band is rather more coarsely crystalline than that of the bands just described, having the character of an extremely fine-grained granite, through which are often seen little splashes of quartz and tourmaline. This granite is massive and uniform in character over large areas, but in many places possesses a very faint foliation, which on the shore of Lake Tangamong in places becomes more pronounced, the rock passing into a very finely foliated quartzose-muscovite gneiss.

A microscopic examination of specimens of the rock taken from lot 25, concession II, and from lot 26, concession III of the township of Lake, shows that the rock is composed almost exclusively of quartz and orthoclase, the latter frequently having the form of microcline, the accessory constituents being represented by a very small amount of magnetite and biotite, and an occasional flake of muscovite. The constituent grains are more or less flattened, and the quartz shows marked undulatory extinction.

Another specimen from lot 16, concession I of Wollaston, has the same composition, the potash feldspar, however, often showing a microperthitic intergrowth of plagioclase. The rock shows, even within the area of a single thin section, a curious variation in size of grain, portions being as fine in grain as one of

the typical felsites above described, while other portions have the texture of an ordinary rather fine-grained granite. A study of this section leads to the conclusion that the coarser grained portion has been developed from the finer grained parts by re-crystallization.

It was found impossible to determine the relations of this band to the associated amphibolites with absolute certainty. On concession I of Wollaston it seems to cut the amphibolite. On the shore of Lake Tangamong the fine-grained foliated granitic rock holds numerous darker streaks, often sharply folded back upon themselves. The appearances suggest that the former cuts the latter and encloses fragments of it, and that the whole mass has been folded and flattened out by the pressure which gave rise to the foliation of the rock.

A comparative study of these three belts leads to the conclusion that all are formed of one and the same rock, which has the composition of an orthophyre, but that processes of crystallization, probably of the nature of devitrification, have taken place in the rock, and have become progressively more pronounced on going north in the area, so that while the rocks are everywhere holocrystalline, the finer grained aggregates, many of them still showing the flow structure distinctly, are confined to the southern area, the central belt being represented on an average by rather coarser grained varieties, and the most northerly bands by rocks which partake of the nature of a very fine-grained reddish gneiss, although practically free from iron-magnesia constituents.

The felsites of the central band, as has been mentioned, fade away into the Copeway Lake granite, where these two rocks come together. This granite when examined under the micro ope is found to be composed of the same constituent minerals as the felsite, namely, quartz, much microcline, some plagioclase, in places altering into a colourless mica, with a little biotite and magnetite. This granite, while not presenting any field evidence of having been submitted to pressure, when examined in thin sections shows the quartz to be much twisted, and exhibiting very marked undulatory extinction.

These felsites which are, as has b own, of volcanic origin, lie around this lenticular area of the Copeway Lake granite, which probably marks the deep seated centre of volcanic activity, and they become intercalated with, and they seem in some cases to

fade away into the rocks which have been classed as clay stones and amphibolites in the southwest portion of the township of Lake, many of which probably represent sedimentary material intermixed with volcanic ashes, but which are now, for the most part, so highly altered that it is impossible to determine to what extent the rock owes its origin to the ordinary agencies of sedimentation, and how far volcanic material has contributed to its composition.

THE PALÆOZOIC OUTLIERS.

The transgression of the Palæozoic sea along the southern border of the great Archæan protaxis in Central Ontario began early in Cambro-Silurian time. This marine invasion was inaugurated by the shallow water conditions resulting in the deposition of certain conglomerates, grits, and sandstones, which mark the base of the Lowville (Birdseye) and Black River formation.

This submergence of southern and southwestern Ontario must have been gradual, the Palæozoic ocean reaching its greatest depth and extent about the beginning of the Trenton. With the exception of minor oscillations of level, which at intervals brought about an alternation of shallow and deep water conditions, there was a gradual emergence of this area from beneath the sea, which culminated in conditions of dry land about the close of the Devonian.

Owing to inequalities of the pre-existing land surface of the Central Ontario highlands, as well as to the subsequent uneven application of the forces of erosion, the present line of contact between the Palæozoic and the Archæan is for the most part very intricate. As a consequence large irregular-shaped masses of flat-lying Palæozoic strata extend for many miles northward beyond the general direction of the line of junction, while corresponding insets of highly inclined Archæan rocks break up the continuity of the main mass of the Palæozoic rocks. This irregularity in the line of division between these two formations is further accentuated by the occurrence of outliers of flat-lying Palæozoic rocks, some of which are now separated by intervals of many miles from the main mass to the south.

On the Bancroft map three of the largest of these outliers lie to the north of Stony lake, in the townships of Burleigh and Harvey, near its southwestern corner. They are entirely separated from one another, as well as from the main Palæozoic area which outcrops to the south of Stony lake in the northern parts of the townships of Smith and Dummer.

PLATE LXV.

Landscape looking north from second concession of Burleigh. Showing in the foreground the good farming land underlaid by the flat lying Palaeozoic. Broken country with hills and hummocks of Laurentian gneiss in background

Other notable outliers occur on the east side of Oak lake, covering portions of lots 2 to 6, in concessions IV and V of the township of Methuen, and at the Vansickle settlement, covering lots 4 to 6, concession I, on the town line between Lake and Methuen.

A very small outlier also occurs on the boundary between Lake and Tudor on lot 4, concession XI of the first mentioned township, while still another outlier was seen on lots 11 and 12, concession VIII of Methuen, being crossed by the road from Kasshabog to Stony lake.

Many of these outliers form rather conspicuous hills, with steep, often terraced escarpments, facing towards the west and northwest. Much of the area underlaid by these comparatively undisturbed formations is either quite level or only gently sloping. From an agricultural standpoint they are in marked contrast to the rocky and usually sterile Archaean country which surrounds them. (See Plate LXV). This is very noticeably the case in regard to the Oak lake and Vansickle outliers, which appear as oases in a desert of rocks, each giving support to a small but prosperous farming community.

There is a remarkable similarity in the succession of the strata which make up all of these outliers. At the base is a fine conglomerate or coarse grit, the larger fragments being rarely more than three-quarters of an inch in diameter. These pebbles are generally of grey translucent quartz, sometimes rounded, but very often subangular, or even angular, usually with a thin film or coating of iron oxide surrounding them. These larger quartzose fragments are embedded in a matrix, made up for the most part of the same mineral in a finer state of division, together with a considerable proportion of argillaceous and calcareous material. A large amount of hydrous iron oxide is present, which gives a prevailing deep brown colour to the rock, especially those portions which are comparatively free from the larger pebbles and fragments. This conglomerate passes upwards by insensible gradations into a coarse sandstone, also reddish-brown in colour. Other beds intimately associated with and superimposed upon it are of finer grained mottled greenish-grey and brownish sandstone. These conglomerates, grits, and sandstones make up a thickness varying from 15 to 20 feet.

These form the basal beds of the Palæozoic section in this section, and overlie unconformably the Archæan gneisses, schists, and crystalline limestones. As a rule only a very few obscure organic markings were noted, which resemble scolithis or buthotrephis. They are not, however, sufficiently well preserved to admit of precise identification. These sandstones pass gradually upward into unevenly bedded yellowish-grey shaly limestone, some of the lower beds containing a considerable quantity of arenaceous material.

The rest of the upward succession includes thicker and more numerous beds of fine-grained grey limestone, which gradually becomes more massive towards the summit of the series. At or near the summit of the Oak Lake and Vansickle outliers occurs a bed of very fine-grained grey limestone, greatly resembling if not identical with the compact lithographic stone of many of the sections of these rocks further to the south in Central Ontario. The complex of Archæan rocks which unconformably underlie the flat-lying strata of the Oak Lake outlier consist essentially of very fine-grained and evenly foliated granitite-gneisses, interfoliated with much larger areas and masses of deep green amphibolite. Near the crossing of Otter creek, on the Marmora road, there are also included certain subordinate bands of light grey gneiss (paragneiss) resembling sillimanite gneiss, which in certain places shows the very characteristic rusty weathering due to the oxidation of the included sulphide minerals. There was also noticed a band of pink-banded rusty weathering dolomitic limestone. These rocks are all interfoliated with one another, the strike varying from N. 50° E. to N. 75° E., with dips to the southeast at angles varying from 30° to 50°. They have very obviously been greatly disturbed and brought into their present highly inclined position long prior to the deposition of the almost horizontal beds of the Palæozoic. They have also in this very early period been greatly weathered and denuded, so that the surface upon which the Palæozoic strata were laid down presented the same uneven or hummocky surface which is everywhere so prevalent in Archæan areas now exposed at the earth's surface. The total thickness of strata in the Oak Lake outlier is probably a little over 100 feet.

The basal beds are well exposed on the side road which connects with the main road from McCutcheon's landing on the east

shore of the lake. Here the lowest bed of the conglomerate rests directly upon the uneven and hummocky surface of the Archæan, at a height of about 40 feet above Oak lake, while the highest bed near the north end of the outlier is nearly 160 feet above the lake. Mr. W. A. Johnson, of the Geological Survey, who collected fossils from similar beds at Longford, and Uphill, Ontario, gives in the Summary Report for 1908 the following determination made upon his collections by Mr. E. O. Ulrich:

FOSSILS FROM BED I.

Rafinesquina minnesotensis, Winchell.
Strophomena filitexta, var. (Lowville var).
Cyrtodonta sp. undet.
Liospira progne, Billings.
Liospira vitruvia, Billings.
Leperditia fabulites, Conrad.
Isochilina armata, Walcott.

FOSSILS FROM BED II.

Tetradium cellulosum, Hall.
Phytopsis tubulosum, Hall.
Strophomena cf. filitexta.
Gyronema sp. undet.
Leperditia fabulites, var.
Isochilina armata, Walcott.
Bathyurus extans, Hall.
Bathyurus spiniger, Hall.

The fossils from bed I were collected from the lowest fossiliferous limestones, as described in the above mentioned section at the Longford quarries, and the fossils from bed II were collected from the fine-grained, dove-coloured limestones immediately underlying the dark-coloured, heavy beds at the top of the section, which latter beds have been referred to the Black River limestone.

Mr. Ulrich states (letter March 9, 1909), that these fossils are all of Lowville (Birdseye) species. With regard to the shales, arkose, etc., at the base of the section, he says: "What the basal 20 feet of red and green shales, thin sandstones, and arkose may

be, I do not like to decide at this distance from the outcrop. I strongly suspect, however, this variable bed is merely the initial deposit of the Lowville. Just such sediments are to be expected, whether it is the Lowville or the Pamelia that first overlaps the old pre-Cambrian land."

These lower beds may therefore be considered to belong to the Lowville (Birdseye).

Dr. H. M. Ami, of the Geological Survey, who examined many of these outliers some years ago, mentions that buthotrephis remains are characteristic and abundant in the thinly bedded limestones which overlie the conglomerates and sandstones, which two latter he includes under the title of Rideau formation. It is quite certain, moreover, in the area covered by the present map sheets, that these shallow water formations are merely the initial deposit of the Birdseye, and not as sometimes described, Potsdam.

Farther up in the series are two beds which are characterized by the abundant presence of Leperditia, while the limestone at the summit holds amongst other organisms *Stromatocerium rugosum*, *Actinoceras Bigsbyi*, *Orthoceras sp?* all pre-eminently characteristic of the Black River formatio .

The succession of the Vansickle settlement is essentially similar to that at Oak lake, but the section is neither so complete or impressive. The outlier which outcrops on the road between Kasshabog and Stony lakes is a shallow formation, as it includes only a portion of the so-called Rideau formation, or basal conglomerates and sandstones, the original overlying limestones having been removed by erosion. The preservation of these basal beds is explained by the fact of their occurrence in a valley, being protected by the Blue mountains on the north, and the hills of granite which border it on the south forming the north shore of the western arm of Kasshabog lake. Although by no means a conspicuous elevation it is known to the settlers as Oak Ridge, on account of the difference in the general character of the t s from that of the surrounding Archæan area.

ECONOMIC RESOURCES.

GOLD.

Craig mine.—These workings are on a quartz vein running parallel to the schistosity (northeast), cutting a fine-grained amphibolite, which is part of the large body of this rock shown as extending through the eastern part of Tudor, and extending thence northerly into Cashel, and east into Grimsthorpe. It averages about 8 feet, although it occasionally widens to 20 feet, holding a certain quantity of sulphides, mainly iron pyrites, and some free gold.

The mine is located on the south halves of lots 4 and 5, concession III, Tudor township, some eight miles northeast of Bannockburn station, on the Central Ontario railway. From facts gathered, this would appear to be a large vein of low grade, but with pretty uniform values in places; the average running about $5 per ton; part of this is free gold, but a considerable proportion is associated with sulphides which entail concentration.

One of the great difficulties in working this mine on a large scale is the question of fuel, wood being the only fuel available at present; the long haul and bad roads making coal too expensive

Work was begun on this deposit some 25 years ago, and after changing hands several times, the property is now owned by the Craig Gold Mining and Reduction Company. The workings consist of two shafts of 200 feet and 100 feet respectively, sunk on the vein 370 feet apart, and connected by a level at 60 feet from the surface. At the bottom of the deeper shaft drifts were driven on the vein 80 feet to the northwest and 65 feet to the southwest.

A very complete stamp mill and concentrating plant has been erected to treat the ore. It consists, in the main, of a jaw crusher, two batteries of 3 Merrall stamps each, and four amalgamating plates; and two Wilfley tables. There are moreover two boilers of 80 horse power each, hoist, compressors, etc. In September, 1907, the mine had been closed down for several months, but it was expected that work was to be resumed shortly.

On the north end of lot 30, concession XIX of Grimsthorpe township, a shaft was sunk to a depth of 35 feet, on a quartz vein striking northeast and southwest, which carries sulphides, mainly iron pyrites, and is said to be gold-bearing. A shipment of three tons of selected ore from this excavation is said to have yielded over $90, or about $30 a ton.

The vein cuts a dark greenstone, fine-grained, probably a diorite, which, in places, has a very schistose texture, more especially near the walls of the quartz vein. At the surface there are two veins of quartz, each about 15 inches wide, which join at a depth of 25 feet, forming a lead about three feet wide. This property is now owned by Mr. Lundenburger of Belleville, Ontario.

Samples of quartz collected from the Higman mine, on lot 9, concession VII of Limerick, assayed in the laboratory of the survey, proved to contain no gold, and only 0·175 of an ounce of silver to the ton of 2,000 lbs.

Other samples collected from large irregular masses of quartz cutting crystalline limestone on lot 31, concession VI of Cashel, were found to contain neither gold nor silver.

COPPER.

A copper-bearing vein has been worked by means of a shaft sunk to a depth of about 35 feet, on lot 22, concession III of Dungannon township, a short distance northwest of Turriff station, on the Central Ontario railway.

The vein appears to be a fissure striking northwest and southeast, in a country rock of amphibolite and limestone bands. When seen, the water in the shaft was about 25 feet from the surface, and at that level the vein was between 3 and 4 feet wide. The gangue is almost altogether calcite. The ore consists of a little bornite, chalcopyrite, and a good deal of pale-coloured iron pyrites. A dump of selected ore was lying at the mouth of the shaft, and for the amount of work done, the quantity of ore extracted seemed to be rather small.

LEAD.

Galena deposits have been known for a long time to occur in the southern part of the area covered by the Bancroft sheet, more

particularly in the townships of Lake and Tudor, and as far back as 1866 Mr. Macfarlane mentions several of these occurrences in the report of the Geological Survey for that year. In the report for 1866-69, Mr. Vennor reviews the most important of these deposits, and the following paragraphs are extracted from it. As the report is now out of print, and is difficult to obtain, it is thought advisable to quote from it rather freely:

"Most of the localities known as affording galena have been noticed in Mr. Macfarlane's report for 1866, but during my explorations in Tudor, having visited all the lead-bearing lodes, openings were found to have been made in some, of which the localities only had been previously indicated, and one or two were in a better condition for inspection than at the time of Mr. Macfarlane's visit.

One of these on the twenty-eighth lot of range B, in Tudor, is is a vertical vein running N. 70° W., the strata of calc-schist dipping 274° < 76. At the time of Mr. Macfarlane's visit, a shaft, which had been sunk on it to a depth of thirty-seven feet, was half full of water, preventing him from doing more than to state the information he had received from others. In 1867, I found that the lode, of which the veinstone is barytes, and calc-spar had yielded on the average three-quarters of an inch of galena; but the bottom of the shaft showed no more than half an inch of barytes, without galena. I was informed by Mr. W. Kesterman, of Belleville, then superintending the mine, that there had been extracted from the vein about six tons of galena, four and a quarter tons of which were sent to New York for sale, after being simply crushed and found to yield 66 per cent of lead.

On the thirty-first and thirty-second lots of the range east of the Hastings road, in Tudor, a lead-bearing vein runs in a vertical attitude N. 57° W., cutting the grey calc-schists with strike N.N.E.

In 1867 it had been traced in the direction given, across both the lots mentioned, with very good surface indications, and was known as the Murphy mine. The Hastings Lead Mining Company subsequently sunk a shaft on it, which, I understand, has been carried down to a depth of 125 feet, but the result being unsatisfactory, the work was abandoned.

On lots 28 and 29, concession XIV of Tudor, there is a vein of red and white heavy-spar holding galena, and cutting

the grey calc-schists. Its bearing is N. 5° E., and it stands in a vertical attitude, while the enclosing rock, also vertical, strikes almost due north and south. It was discovered some eight years ago, and was first opened in 1859. In 1867 the mine was leased by Messrs. Lombard and Co., of Boston, who were working it at the time of my exploration in Tudor, and I had an opportunity of examining the shaft when free from water. The walls were regular and well defined, the width between them being in some parts from eighteen inches to two feet, and the ore appeared in scattered and irregular bunches in the gangue. When first opened, this vein yielded some large masses of ore, but, as in a previously mentioned instance, they greatly diminished, descending, and at the bottom of the shaft, which was twenty-five feet deep, there was scarcely any ore. In 1868, at the depth of forty-two feet, the mine was abandoned. It may be remarked that many of these veins in Tudor, yielding considerable bunches of ore near the surface, show little more than traces of galena at the depth of a few feet. Of twenty-five localities in Tudor, in which galena was discovered and partially worked, only one, the Murphy mine, continued to be worked in 1868.

The west half of lot 10, concession XI of Lake, is another of the localities mentioned by Mr. Macfarlane. On this lot, which was some time since bought by Messrs. Gillum and Kesterman, of Belleville, occurs the Donahue vein, striking N. 50° W., and standing in a vertical attitude. Little, however, has here been done, and although the lode has a width in some parts of from twenty to twenty-four inches, bounded by regular walls of grey calc-schist, the galena occurs only in scattered and irregular patches, and in considerable quantity.

On lot 8, concession XI of Lake (or possibly in concession X) a vertical vein, holding galena in a gangue of heavy-spar, runs through the calc-schist in the direction N. 45-50° W. The lode varies in thickness from ten to eighteen inches, and is bounded by well defined walls. Little had been done on this lot up to 1867, but in the short distance then uncovered, I saw extracted some masses of ore, at the depth of three feet from the surface, which weighed from fifteen to forty pounds, and I was informed that when first discovered much larger masses had been taken from the vein. The lode is supposed to be on the

property of Mr. Wm. Sweeny, of Tudor, but in consequence of the defective manner in which the township has been surveyed there at present exists a dispute as to the ownership of the lot.

The lead-bearing veins just noted, I believe to be the most important in Tudor and Lake, so far as examined. In these townships there appear to be two distinct sets of these veins: one of them running northwest, and the other northeast by north, those in the former direction being the more numerous. Where such veins cross one another there appears in general a fair show of ore at the surface, which, however, as in other cases, often diminishes at the depth of a few feet."

Since then only two important finds of galena have been made on which much work has been done. These are the Katherine mine, situated on lot 6, concession XI, Lake township, which was first opened up in the spring of 1899; and the Hollandia vein, which is situated on lot A, concession VI, Madoc township, immediately south of the southern limit of the Bancroft sheet.

The Hollandia mine is being worked by the Ontario Mining and Smelting Company. The galena occurs rather unevenly disseminated in a gangue of calcite, filling a zone of dislocation running S. 54° E. and cutting the highly inclined amphibolitic schistose rock, of which the strike is N. 45° E. At the time of Mr. Denis' visit, the workings consisted of three shafts, having respective depths of 150, 100, and 70 feet, with about 600 feet of drifting. A complete mining and concentrating plant has been erected, consisting of two boilers aggregating 180 H.P., Cornish pump, hoist, drills, engines, jaw crusher of a capacity of 60 tons per day, rolls, jigs, etc.

The Katherine mine is situated about three miles west of Millbridge. The vein and associated rocks are very similar to the occurrence worked at the Hollandia mine, with the exception that a considerable proportion of zinc blende accompanies the galena.

A shaft was sunk 125 feet deep, and at a depth of 100 feet a level was driven north 100 feet, and some stoping done. Half a mile south of this shaft another was sunk to a depth of 18 feet. Some prospecting was done by means of a drill, and a hole 292 feet deep was made.

Other localities which may be mentioned on which galena has been found are as follows:

Lake, concession	XI, lot 11.	
Tudor, concession	III,	" 32.
"	V,	" 12.
"	VI,	" 11.
"	VII,	" 10.
"	XIX, lots 26, 27, and 28.	
"	A, lots 21-28.	
"	B, lots 5 and 6.	
"	B, lots 27 and 28.	
Limerick, concession	II, lots 27-29.	

MOLYBDENUM.

. what is as nearly as could be ascertained the N.E. corner of lot 3 of concession I of Harcourt, near the shore of Farquart lake, there is a great body of granular green pyroxene rock, to which reference has been made in describing the alteration which has been induced in the limestones by the granites. This mass is about a hundred yards wide, forms a low hill, and is bounded on three sides by the gneissic-granite, and on the fourth by drift. The strike of the gneiss curves around the mass, which is without doubt a limestone inclusion completely altered to pyroxenite. It is traversed by little strings of feldspar, in some places showing Baveno twinning. There are also little nests of coarsely crystalline calcite found in the pyroxenite here and there, as well as crystals of tourmaline and sphene. Running through the rock there are small veins and strings of pyrite and molybdenite, with small amounts of pyrrhotite. At the time the locality was visited in 1898, a shaft about 15 feet deep had been sunk, and many fine specimens of pyrite and of molybdenite had been taken out. Since that time further work has been done in opening up the deposit, by Mr. Dillon Mills, for the Land and Immigration Company (Limited), of Haliburton, on whose property it is situated. A number of small veins of pyrite, holding molybdenite and traces of copper pyrite, were discovered by Mr. Mills, when the work was discontinued, as enough had been done to show the probability of molybdenum in quantity. Plates of molybdenite from one to two inches in diameter were found in the deposit.[1]

[1] See also Ann. Rep. Bur. Mines, Ont., 1902, p. 47.

A deposit of molybdenite was found in the summer of 1901 at a point three miles southwest of Deer lake station, in the township of Cardiff, by Messrs. C. M. McArthur, and C. E. Taylor, of Fenelon Falls. The locality was not visited, but a considerable amount of the mineral taken from the deposit was examined. It is very pure and of good quality, some of it occurring in the form of nearly perfect hexagonal crystals an inch in diameter.

A molybdenite mine was also visited on lot 16 of concession VII of the township of Digby. The mineral was found to occur as a little string, five inches in length and an inch and a half wide in quartzose grey gneiss, and was therefore of no economic value. The mineral, however, is pure and of good quality. The mineral also occurs in small amount disseminated through an impure crystalline limestone, on lot 23 of concession V of the township of Lutterworth, by the shore of Eastmores lake. It also occurs in small amount, in flakes and crystals, in the gneiss at Miners bay, on the east shore of Gull lake in the same township.

On lot 6, concession I, of Monteagle, a few shots have been put in on a narrow vein of quartz and fibrous hornblende containing scattered scales of molybdenite. The occurrence does not seem to be of economic value. The mineral is also found on lots 26 and 27, concession VI of Monteagle, and on lot 24 or 25, concession XIV of Anstruther.

IRON ORE.

Burleigh. Ore[1] from a deposit of black, fine granular magnetite in the northern part of Burleigh township, near Apsley village, was found by Chapman to carry: iron 63·68 per cent; phosphorus, a trace only; sulphur, 0·03. The intermixed rock matter is pyroxenic. The deposit was in 1890 undeveloped.

Dungannon, lot 30, concession XIII. On the southern part of lot 30, concession XIII of Dungannon, some work was done on a deposit of magnetite, which occurs in the nepheline syenite. The ore is found in patches, mixed with large crystals of nepheline, and is probably the result of a process of differentiation of the magma. As might be expected from its nature, the deposit is very irregular.

[1] Trans. Am. Inst. Min. Eng. xix, p. 35

most of the patches or lenses observed not being more than six or seven inches wide. The work done on the deposit consists of a small open pit, from which a few tons were extracted. The ore itself looks very pure.

Iron mine, Glamorgan, lot 27, concession XV. On this lot there are several veins, the largest of which was in places as much as four feet in width, and could be traced for over sixty yards. These veins cut through a rock which has the appearance of a mica syenite, and are filled with a coarsely crystalline aggregate of pale pink calcite, with apatite, sphene, biotite, hornblende, orthoclase, and magnetite. The magnetite, which shows good octahedral forms, is strongly attracted by the magnet, and in places is itself a natural magnet. It constitutes about one-half of the principal vein, but the quantity is entirely too small to permit of the deposit being seriously considered as a source of iron, quite apart from the presence of apatite and sphene in considerable amount.

One of the veins has been opened up for the purpose of obtaining the mica, which is relatively more abundant in it. Specimens of the mica up to six inches in diameter were obtained, but the mineral is very dark, in fact, black in colour. (See Page 200.)

"[1]The ore body conforms to the strike of the gneiss, but is irregular in width. In one of the main openings it is 35 feet wide. This, however, is not all iron ore, since—as is the case with so many of the iron ore deposits in these Laurentian rocks—the ore itself is mixed with a large quantity of various black ferruginous silicates, such as hornblende, pyroxene, and garnet. The ore body is also cut by many reticulating veins, holding quartz, calcite, orthoclase, pyroxene, scapolite, allanite, and other minerals. The ore is almost free from pyrite and other sulphides, and specimens selected by me, and examined in the laboratory of the Survey, were found to be free from titanium, but, as above stated, it contains a large proportion of various silicates, amounting in the case of a sample examined by Professor Chapman to 23·80 per cent, while other samples would give considerably higher percentages. The presence of these silicates, however, while lowering the percentage of iron, produces an ore which is easily smelted, and which

[1] Annual Report, Geological Survey of Canada, (New Series), vol. vi, p. 8 J, 1892-3.

closely resembles the so-called self-fluxing ores of Sweden. The following analysis of the average ore from this Paxton mine is given by Mr. Hamilton Merritt:—

Fe_3O_4	67·77	(Metallic iron =48·64
SiO_2	19·30	
Al_2O_3	6·24	
CaO	3·81	
Mg	3·38	
S	0·03	
P	none.	
TiO_2	0·15	
	100·68	

Pine lake, Glamorgan, lot 35, *con.* 4.—[1] Here a large deposit of granular, black magnetic ore forms a ledge, or succession of ledges, rising to a height of 80 or 100 feet above the general level of the district. It is exposed for a length of 1,800 feet, and has a width varying from 70 to 198 feet. Reference has been made to the microscopic character and geological relations of this deposit in that portion of the report concerned with a description of the gabbros. An analysis of a sample taken from different parts of the deposit yielded Dr. Chapman the following results:—

Fe_3O_4	71·87
TiO_2	13·30
$CaCO_3$	0·86
Rock	15·28
Fe	52·04
P	trace.
S	0·06
Sp. Gr.	4·437

[1] J. F. Kemp.—School of Mines Quarterly, xx, p. 329.

The following is the result of an analysis made by F. J. Pope:—

Fe_2O_3	39·27
FeO	21·73
MnO	0·37
NiO	·27
CoO	·07
Al_2O_3	4·61
SiO_2	10·77
P_2O_5	·02
S	·11
TiO_2	13·52
V_2O_5	·52
MgO	2·34
BaO	·07
CaO	4·84
Na_2O	·31
K_2O	.24
Moisture	.44
Total	99·50

Although the deposit is very large the high percentage of titanium has prevented its utilization. A large hole has been blasted in it.

Glamorgan, lots 29, 30, *and* 32, *concession* I.—Small strings of a magnetic iron ore are found in the belt of amphibolite which crosses this corner of the township. All those observed were quite narrow, the thickest having a width of only six inches, and they conform in strike to the foliation of the enclosing amphibolite. It is possible that a careful prospecting of the district might result in the discovery of thicker seams. A specimen of the ore from lot 32, concession I of Glamorgan, was tested for titanic acid by Mr. Howard, in the Chemical Laboratory of McGill University, and found to contain a small percentage of this substance.

Glamorgan, lot 27, *concession* XIII.—Chapman[1] describes this as a black crystalline, highly cleavable ore. "It holds 70·38 per cent metal, no trace of titanium, and merely traces of phosphorus and sulphur. The ground is quite undeveloped, but there are a

[1] Trans. Royal Soc. Can., 1885, sec. iii, p. 11.

few exposures; and needle attractions show a strong body of ore, ranging N. 65° E., over a length of about 400 feet by 40 feet in width. A second and apparently isolated deposit of similar character, occurs on another part of the same lot."

Lake, lot 18, *concessions* III *and* IV.—A considerable body of iron ore crosses near the line between concessions III and IV of the township of Lake, on lot 18, about a couple of hundred yards east of the Deer river. This is a black magnetic ore, holding only a very little iron pyrite, and was traced along the river bank parallel to the strike of the enclosing rock for a distance of over 200 yards. In this band a width of six feet of nearly pure ore is exposed in one place, and a width of three and a half feet in another. A specimen of this ore, collected on lot 18 of concession III, was found to contain 60·09 per cent of metallic iron, and to be free from titanic acid.

The succession of strata here, going back from the river to the east for half a mile across the strike, is as follows: —By the river side micaceous felsite occurs with amphibolitic bands. This is followed by a light coloured metamorphic rock composed of a fine-grained base, which, under the microscope, is seen to consist of orthoclase with a little biotite, through which base are distributed large crystals of scapolite, associated with smaller crystals of deep brown hornblende, black iron ore, and a little calcite. This is succeeded by rocks similar to those found by the river side, containing bands whose appearance suggests that they are metamorphosed volcanic ashes, and in these is a band of fine-grained green magnetite-actinolite rock consisting of actinolite with about 10 per cent of magnetite. The iron ore occurs with this rock. This belt of iron-bearing rock is closed by a mass of gabbro, in which the original pyroxene is now completely altered to a green hornblende, and in which the iron ore originally present is represented by skeleton forms such as those produced by the alteration of ilmenite into leucoxene, the interspaces of the skeleton forms in this rock, however, being filled chiefly with hornblende, although some leucoxene is present. This rock is in a highly altered condition, but from the shape of the plagioclase which it contains it seems to have originally possessed a diabasic structure. Beyond this is a band of conglomerate fifteen feet wide, containing pebbles of granular white quartz rock (probably vein quartz), as well as some pebbles of a magnetite-actinolite rock like that above described.

and others of reddish feldsite. The pebbles are well rounded in most cases. (This conglomerate is also referred to on page 47). Succeeding this conglomerate, felsite occurs, with intercalated beds, whose appearance suggests a derivation from volcanic ash-flows like those referred to above. A thin section of one of these ashy looking rocks, which consisted of alternate pink and dark grey layers, was examined under the microscope. The pink bands were found to be composed of microcline, with a smaller amount of quartz, forming a fine-grained aggregate. The darker bands were found to be identical in character with the pink bands, but to contain numerous little irregular-shaped hornblende individuals, and little skeleton crystals of epidote, which gives to these bands their darker colour. The rock also contained occasional large grains of black iron ore, with a few little granules of sphene, and a few grains of a rhombohedral carbonate. This rock is therefore closely related to the feldsites in this part of the township of Lake, which, as has been pointed out, are of volcanic origin.

Paxton mine, lot 5, concession V and VI of Lutterworth. The country rock is a fine-grained reddish gneiss, interstratified with a small band of crystalline limestone. There are also many small amphibolitic bands. The ore is a magnetite. The ore body conforms to the structure of the gneiss, which is to the east of north with an easterly dip, but is irregular in width. In one of the main openings it was as much as 35 feet across. This, however, is not all iron ore, but consists largely of various dark iron-bearing silicates —garnet, pyroxene, etc., with which the magnetite is mingled. The ore is practically free from pyrite. The ore body is cut by many reticulating veins, holding calcite, quartz, orthoclase, scapolite, pyroxene, and other minerals. A very considerable amount of work has been done on this deposit and a large amount of ore shipped from it.

Mayo, lots 2, 3, and 4, concession VI, and lots 11 and 12, concession IX.—One of the most important deposits of magnetite yet developed in this region occurs on lots 2, 3, and 4, concession VI, and on lots 11 and 12, concession IX, of the township of Mayo. So far as developments allow to judge, there are four distinct bodies of magnetite of large size, on all of which a considerable amount of work has been done. These bodies all occur in the area of amphibolite, which occupies the eastern part of Dungannon township, and

the northwestern part of Mayo. They are designated respectively as mines No. 1, No. 2, No. 3, and No. 4, and are the property of the Mineral Range Iron Mining Company.

No. 1 was originally called the Childs mine, and is situated on lot 11, concession IX of Mayo. This was the first of these bodies of magnetite on which work was done, and several hundred tons of good ore have been extracted from two open cuts. The average contents of the ore in metallic iron is here rather lower than in the bodies of Nos. 2, 3, and 4 mines, being higher in silica and calcite, but it is remarkably low in sulphur and phosphorus, and as the company intends to install a magnetic concentrating plant, it is expected that it will, in the near future, become a large producer.

At No. 2 mine, which is situated on lot 2, concession VI of Mayo, a long open cut reveals a body of magnetite, the walls of which are not well defined.

The ore is coarsely granular, and the deposit contains pockets and seams of a fine-grained greenstone, which in places assumes the appearance of a chloritic schist. Comparatively little work has been done at this place, and developments are at present being concentrated on mines Nos. 3 and 4.

Workings No. 3 are situated near the west line of lot 3, concession VI, and the deposit is separated from No. 2 by only a comparatively narrow strip of country rock. The ore is here rather different in texture. It is more friable than that of the other deposits, but is very free from deleterious elements. A calyx drill hole was put down on this deposit to a depth of 160 feet, all in good magnetite. A large quantity of ore has been, and is now being shipped from these workings, all of which was extracted from an open cut.

Mine No. 4 is located on the eastern boundary of lot 4, concession VI and appears to be on the same strike as No. 3 body, the longer axis of both deposits being on the same straight line. In the case of No. 4, the foot-wall is better defined than in any of the other three deposits, and consists largely of calcareous rock, which may be a phase of the amphibolite. The ore body strikes approximately northeast and southwest, and dips to the south. From a long open cut 150 feet by 50 feet wide, and having a face of 40 to 50 feet, ore is being extracted and shipped. In the upper benches of these workings the magnetite is somewhat mixed with rock matter, mostly a greenish dioritic, fine-grained rock, but in depth,

this admixture disappears, and the bottom of the pit shows pure compact ore. This remark also applies to working No. 3.

A core drill hole was put down on No. 4 deposit to a depth of 148 feet, all in solid ore. At this depth, the bit of the drill broke, and the hole was abandoned before reaching the floor of the deposit.

Comparatively little development work has been done on any of the deposits, beyond putting down the two drill holes mentioned above. But plans are now laid out to keep development work well ahead of mining, and a shaft is being sunk from the bottom of the open cut on No. 4. [1]This three compartment shaft is now down 75 feet on the ore body, dipping at an angle of 67°. From the 50 foot level it will be sunk vertically, as at this depth the ore has less dip than near the surface. At a depth of 50 feet a station has been cut, and levels are driven west 25 feet and east 20 feet. At No. 3 a shaft has been sunk 25 feet, at a point between two lenses of ore, the intention being to hoist from both bodies through the one shaft.

The mining plant of the Mineral Range Iron Mining Company, of which Mr. H. C. Farnum is general manager, consists in the main of two boilers of 80 horse power each, seven steam drills, hoisting machinery, and a large gyratory crusher of a capacity of 1,000 tons a day. It is the intention of the company to shortly install a magnetic concentrating plant, and briquetting machinery, which will enable them to treat the poorer ore which is now accumulating on the dumps and used for ballast on the railway.

The following analyses of ore were furnished by the Mineral Range Iron Mining Company. They are analyses of ten car lots each, shipped to the Midland furnace in May, June, and July, 1907.

Metallic iron.	58·83	57·21	54·43
Phosphorus.	·016	·02	·018
Sulphur.	·062	·058	·061

The ore contains no titanium.

The mines are connected with the Central Ontario railway by a line five miles long, operated by the Bessemer and Barrys Bay railway. This line will be extended to the Childs or No. 1 mine at an early date. The mining camp, which is called Bessemer, is fast developing into a permanent industrial settlement.

[1] Seventeenth Rep. Bur. of Mines, Ont., p. 87

Minden, lot 11, concession I.—The country rock here is crystalline limestone interstratified with well banded gneiss, striking N. 25° E. with an easterly dip at a rather high angle, and associated with coarse pegmatite. The ore, which occurs as a bed or lens in the gneiss and limestone is seen near the side of the lake. It is exposed for a length of 25 paces, and has a width of 10 paces, although the hanging wall is drifted so that the width may be slightly greater. The strike would carry the ore body under the lake in one direction, and into a swamp in the other. As in the case of other iron ores in this district, there is present a very considerable proportion of dark ferruginous silicates, which are so arranged as to give a more or less distinct foliation to the rock. The large proportion of these greatly reduces the percentage of iron in the ore. This ore was tested for titanium by Mr. Howard in the laboratories of McGill University, and was found to be free from this element. Iron ore, stated to be from this same lot and concession, was analyzed by Prof. Chapman, and found to contain 25·51 per cent of titanic acid.

Another deposit similar to that described above, and of about the same dimensions, is reported to occur in the adjacent lot, number 12.

Monmouth, lot 30, concession 13.—[1]The ore here is black, crystalline, highly cleavable. The ground is undeveloped, but samples taken from a trial pit show $70\frac{1}{2}$ per cent iron, with rock matter under 3 per cent.

Victoria mine, lot 20, concession I, Snowdon. This deposit of magnetite has been worked quite extensively, a considerable amount of the ore having been shipped. The ore contains a rather large admixture of dark iron-bearing silicates, and has a not inconsiderable amount of pyrrhotite scattered through it.

The workings, when visited in 1893, consisted of a trench 240 feet long, and about 16 feet wide, opened up on the iron ore bed. The ore bed lies in crystalline limestone, which has interstratified with it occasional strings of green pyroxene rock, red garnet rock, and gneiss. The ore body conforms to the strike of the limestone.

[1] Trans. Royal Soc. Can., 1885, sec. iii, p. 11.

and like it stands nearly vertical, but with a slight easterly dip. The ore body at the north end of the trench is seven feet wide — its actual width in the trench could not be determined as the latter was filled with water. At the south end of the trench the iron ore has been practically all replaced by black hornblende, and other highly ferruginous silicates.

[1] This property was examined by Messrs. Parry and Mills, and tested with a drill to a depth of 300 or 400 feet. They were so well satisfied with it that in 1882 they started the erection of a furnace, a saw-mill, and charcoal kilns, on Burnt river, Haliburton county. These works were well advanced the next year. \$50,000 or \$60,000 had been spent, and about \$10,000 was required to complete them. Money could not be procured and the enterprise had to be abandoned.

The deposit is situated about half a mile from the line of the Irondale, Bancroft and Ottawa railway.

The following is the result of an analysis made by Prof. Chapman: -

Fe_2O_3	58·35
FeO	24·87
MnO	0·13
Al_2O_3	0·42
CaO	1·43
MgO	2·56
P	0·07
S	0·04
SiO_2	11·17
TiO_2	0·73
	99·77

Farther south on the same lot another opening has been made, and some ten carloads of ore were shipped from the deposit prior to 1893. Here also the ore seems to have contained a very large proportion of admixed silicates, the deposit, as before, occurring as a bed in the crystalline limestone, which is here interstratified with impure altered limestone, consisting largely of granular green pyroxene, and reddish garnet.

[1] Rep. Royal Com. on the Mineral Resources of Ont., 1890, pp. 326 and 394.

Snowdon, lots 25, 26, and 27, concession IV.—Near Howland station on the Irondale, Bancroft and Ottawa railway are several outcrops of magnetite.[1] The ore is on high ground overlooking the railway, and very conveniently situated for mining by tunnels run into the hillside.[2] The deposit at the Howland mine, lot 26, lies at the contact of a hornblendic gneiss and a narrow band of limestone. The gneiss presents little banding, but the microscope reveals the effects of considerable crushing. The feldspar is much shattered and altered to scapolite. This secondary scapolite and hornblende constitute nearly the entire rock. Some mica is present, and titanite is plentiful. At a distance of several hundred yards from the mine, augite becomes more abundant than hornblende, and the rock is gabbroic. The limestone is fine crystalline, and carries graphite, small scales of phlogopite, and bunches of silicates, chiefly hornblende. The ore is a fine-grained magnetite, quite pyritous near the surface, but becoming almost free from pyrite with depth. The following analyses have been given:

No.	Metallic iron	Phosphorus	Sulphur	Silica	Titanium
1	61·48	0·01	0·16	.....	none
2	62	trace	0·025	1·17	
3	62·57	·0025	trace	...	
4	63	trace	0·025	3·1	

The first analysis was made by Prof. Chapman from a sample taken at a depth of 81 feet. The others were made by chemists of different iron works in Pittsburg.

Work was begun in 1880, and in 1881 and 1882 1,500 tons were shipped. Work was in progress in 1890, and a shaft 12 feet by 24 feet had been sunk to a depth of 75 feet. A body of ore was removed, 65 feet long and 35 feet wide, and extending from the 25 foot level to the 50 foot level, but no wall was encountered during its removal.

Imperial mine, Snowdon, lot 33, *concession* V. This opening is situated on the north side of the Irondale, Bancroft and Ottawa railway, close by the track and just east of Irondale station.

[1] Trans. Am. Inst. Min. Eng., xix, p. 33.
[2] Trans. Am. Inst. Min. Eng., xxix, p. 376

The ore body forms a ridge which, although surrounded by drift, must occur at, or very near the contact of the limestone with the granite-gneiss of the Glamorgan batholith. The material taken out as ore is composed essentially of olivine and augite, with a smaller amount of hornblende and a little orthoclase feldspar, showing perthitic intergrowths. Only a very few grains of iron ore occur scattered through the rock. The rock is thus really an olivine pyroxenite, and not, properly speaking, an iron ore at all. It possesses a foliated structure, striking approximately parallel to the railroad, and dipping in a southerly direction at an angle of about 35 degrees. There is a large body of the rock exposed, a considerable amount now being ready to ship, and it is stated that a large amount was shipped when the mine was in operation.

St. Charles mine. —This is situated on lot 19, concession XI of Tudor township, about five miles north of Millbridge station on the Central Ontario railway. This mine was opened several years ago, and a good deal of ore has been extracted from this deposit. It is a rich magnetite, running as high as 60 per cent metallic iron; it contains only traces of phosphorus, but runs rather high in sulphur, some shipments having shown a tenor of one per cent of this element. The following notes are extracted from a report published in the annual report of the Ontario Bureau of Mines for 1900.

"The ore is magnetite with more or less calcite, occurring in an apparently well defined vein having a strike north 45° west, lying between dioritic wall-rocks. The vein evidently occupies a position along a fault plane, with which is associated an intrusion of a dark, fine-grained, basic, volcanic rock. There has been movement of the walls subsequent to the original ore filling, followed by deposition of calcite. This was shown by the crushed and broken hornblende crystals healed by calcite."

The working consist of a long open cut some 300 feet in length, and several shallow pits. The mine has not been operated since 1903.

Tudor, lots 6, 7, and 8, concession XIX.—[1] Chapman describes this as a magnetic ore of high grade. "The exposed ore rises in a series of ledges from the level of the ground to a height of from 150 to 180 feet, and extends over a space of at least 1,000 feet

[1] Trans. Royal Soc. Can., 1885, sec. iii. p. 12.

in length by 100 feet in breadth. It is thus, in all probability, an enormous mass or stock, the portion above ground alone including many thousand tons of ore. The ore itself is comparatively soft, and of a fine granular, more or less porous, texture. The analysis shows 63·30 per cent metal, with total absence of titanium, and traces only of phosphorus and sulphur. It is one of the finest ores in this section of Ontario. The intermixed rock-matter (8·36 per cent in my samples) yielded: silica 5·22, lime 1·93, magnesia, etc. (by difference), 1·21. The deposit is known as the Emily mine."

Tudor, lot 18, concession XVIII.—[1] A body of very superior magnetic ore is "exposed in the form of a broken curve or semicircle along the eastern face of a somewhat abrupt ridge or slope, over a length of about 1,200 feet, but it can be traced much beyond that distance. About 500 feet to the south of this exposure a large mass of similar ore, probably an extension of the main body, comes to the surface. Here and there a few specks and thin strings of pyrites are visible, but the ore on the whole is of more than average quality. In the sample taken for analysis the amount of metallic iron equalled 68·16 per cent. In other samples, subsequently examined, it averaged 66 per cent. The intermixed rock-matter is essentially pyroxenic, with very little free silica, and there is no trace of titanium in the ore. The deposit is known as the Baker or Horseshoe mine."

Tudor, lots 56 and 57.—On lots 56 and 57 west of Hastings road, Tudor township, some work has been done on a deposit of magnetite, which occurs at the western end of the lots near the boundary line between the townships of Lake and Tudor. The deposit occurs in an igneous rock, probably a diorite, and has no well defined walls, but seems to gradually merge into the country rock. The main workings consist of an open pit some thirty feet long, fifteen feet wide, with a face of some ten to twelve feet high. A couple of car loads have been shipped, but the work done is not sufficient to give a good idea as to the extent of the deposit. The ore is said to be comparatively free from sulphur and phosphorus, but rather high in titanium.

Wollaston, Coehill.—This deposit forms part of the limestone amphibolite series which is extensively developed in this portion of

[1] Trans. Royal Soc. Can., 1885, sec. iii, p. 12

the township, but which is here locally enriched in iron, probably by one or other of the igneous intrusions which penetrate the series in the immediate vicinity. The ore body is cut through by numerous dikes of the associated red syenite. The ore deposit has a streaked or stratified appearance parallel to its strike, which coincides with the strike of the country rock, and has at the main workings a width of about sixty feet. There are, however, other smaller ore bodies in addition to this main one. The streaked character of the ore body is produced by the variation in relative amount of the constituent minerals present. The whole outcrop weathers to a very rusty colour.

A series of specimens, representing the various varieties of rock comprised in the ore body, were collected and examined microscopically. They were found to consist of the following minerals: magnetite, pyrite, pyrrhotite, pyroxene, hornblende, and calcite. Plates of black mica are also sometimes found in the ore.

As has been mentioned, the ore body varies considerably in character in the different streaks. Those richest in iron, which constitute the ore proper, are found on examination to be made up almost exclusively of iron ore and pyroxene. Other streaks are composed of pyroxene, with little or no associated iron ore, while in others again the hornblende preponderates practically to the exclusion of all other minerals. The pyroxene is a pale green augite, locally becoming somewhat richer in iron, and taking on a deeper green colour. In the same way the hornblende is for the most part poor in iron, being light green in colour when seen in hand sections, and almost colourless as it appears in thin sections.

Associated with these banded varieties of iron ore, pyroxenite, and amphibolite, there are occasional bands of limestone, especially toward the northern limit of the deposit. The ore body was worked in an open cut, and by three shafts or steep inclines which apparently followed the dip of the deposit, which, following the general attitude of the country rock, was southerly at an angle of probably about 70°.

In addition to being rendered impure by the presence of pyroxene and hornblende, the ore contains a very considerable amount of pyrite, irregularly disseminated through it, so that while, by careful sorting, ore may be obtained almost free from

sulphur, elsewhere the sulphides are very abundant, so much so that many of the blocks in the dump pile have in the course of a few years become completely disintegrated through the oxidation of this mineral.

Similar local enrichments of the limestone-amphibolite series, giving rise to lenticular bodies of more or less ferruginous character, several of which have been worked to a small extent as iron ores, occur at a number of places in the vicinity of the Coehill deposit.[1]

This ore body, as will be seen from what has been above stated, is entirely different in origin and character from an occurrence such as that which has been described from lot 35 of concession IV of the township of Glamorgan, in that, while the latter is massive in character and is a product of the differentiation of an igneous magma, the Coehill ore body, as has been mentioned, has a more or less stratified character, and represents a portion of the stratified limestone-amphibolite series locally enriched in iron.

OCHRE.

Loon bay, Hollow lake, township of Sherborne, concession XII. By the side of Loon bay there is in the drift a deposit of ochre. The raw material contains about one-third of its weight of sand. It is dug up and first burnt in a series of badly constructed pans, then ground between stones and passed through a fine sieve. The sand in this way is believed to remain upon the sieve, while the finished ochre passes through. The raw material is yellowish brown in colour, the burnt ochre having a deeper brown color. The plant consists of two buildings, containing burning pans, each capable of handling somewhat less than half a ton of the ochre per diem, together with grinding stones and sieves, and a steam engine to supply the necessary motive power. The total capacity of the plant is about 3 tons per diem. There is also a boarding house for the employes. The property was stated to be owned and operated by the Peterborough Mining Company. Two men were employed about the works at the time the locality was visited in the summer of 1896.

[1] See Ont. Bureau of Mines, 1902, p. 262. "10,000 tons magnetite reported shipped from the stock piles last year without resumption of mining."

PYRITE.

[1]The Little Salmon lake deposit is located on the shore of Little Salmon lake, on lot 23, concession VII of the township of Cashel, Hastings county.

"A hill rises sharply above the level of the lake to a height of eighty feet. Half way up the hill a trench forty feet long has exposed a deposit of pyrites. In the north end of the trench, the pyrite uncovered is fifteen feet wide. An average of 75 per cent of the pyritous material yielded 38·83 per cent of sulphur. The country rock of the deposit is a chlorite schist, and the strike is east and west.

"The Central Ontario railway is nine miles distant by winter draw at Gilmour, and six miles winter draw across Big Salmon lake to the gravel pit.

"The Gunter property is situated on lot 23 in concession IV of Cashel.

"A shaft has been sunk on the lead to a depth of twenty feet, in alternate bands of quartz and pyrite. The work was done while prospecting for gold. The soil on the surface is quite unaltered, and no gossan, fahlband, or other indications of a pyrite deposit are visible. The pyrites in the shaft, however, uniformly increased with depth. A sample representing two-thirds of the dump yielded 39·50 per cent of sulphur. The total width of the vein is five feet.

"The Central Ontario railway is seven miles distant by summer road, and six miles by winter haul."

MISPICKEL.

Jeffrey prospect.—Located on concession IX of Faraday township, 7 miles directly west of L'Amable station, Central Ontario railway, and owned by James Best, of Bancroft. It shows a vein of mispickel, quartz, etc., 4 feet wide, but opened up at one spot only, where a shaft has been sunk 10 feet. A sample taken by the writer and assayed at the Government assay office gave per ton of ore:—

Gold.	·06 oz.
Silver.	3·01 ozs.
Metallic arsenic.	27·54 p.c.

Ontario Bureau of Mines, 1902, p. 102.

[1] Sixteenth Annual Rep. Bureau of Mines, Ont., 1907. Part i, p. 163

In specimens obtained from the locality Dr. Adams also found small quantities of three other arsenic minerals, namely: realgar, orpiment, and scorodite. (See p. 205)

Mispickel also occurs on the Bradshaw lot, on concession VI of the township of Dungannon where it is associated with quartz and scorodite.[1] It is also found on the Rollins lot, five miles east of Coehill, in the township of Wollaston.

MICA.

Township of Monmouth, lot 16, *concession* X. A deposit was opened up here some years since by Alex. Watson, of Kinmount, on the property of Richard Hales. The mineral occurs in a coarse-grained streak of calcite and mica in the limestone of this locality. A few crystals of apatite were observed, associated with the two minerals above mentioned. The mica is dark brown in colour, and crystals 5½ inches in diameter were collected. No work was being carried on at the time the locality was visited.

Township of Cardiff, lot 7, *concession* XXII. This mica occurs associated with some calcite in a mass of the dark green granular pyroxenite, so often found as an alteration product of the limestone. The mica occurs in large plates, some measuring as much as two feet by two and one half feet were seen, but the mineral is very deep brown, nearly black, in colour. The opening is situated by the side of the track of the Irondale, Bancroft and Ottawa railway, and the deposit was owned by Messrs. Best and Membry. Four men were at work at the time the locality was examined, a hole 20 feet square and about 18 feet deep having been excavated, and a considerable amount of the mica taken out. Work was subsequently discontinued, owing, it is stated, to certain legal complications having arisen.

Messrs. Hughes and Colter, of Bancroft, opened up a deposit of what seemed to be a biotite, on lot 30, concession XIII of Cardiff. Many of the crystals are very large, and free from checks or inclusions, but they are very dark in colour. The mica occurs in a vein, with crystals of albite, orthoclase, and pyroxene, in a gangue of calcite.

Township of Glamorgan, lot 35, *concession* I. At this locality black mica occurs in occasional patches or segregations in the

[1] Eleventh Rep. Bur. Mines, Ont., p. 198.

syenite which forms the country rock. These are sometimes as much as two feet in diameter, giving individual sheets of mica several inches across. The mica is, however, a good deal broken, and is very dark in colour. The occurrences are of little or no economic value. The syenite also contains occasional little strings of white mica. Such are frequently found in connexion with specimens of corundum. The latter mineral was not, however, observed, although it is quite likely that very careful prospecting would lead to its discovery.

A deposit of mica was also opened up during the summer of 1901 by Messrs. C. M. McArthur and C. E. Taylor, of Fenelon Falls, at a point about half a mile from Wilberforce, a station on the line of the Irondale, Bancroft and Ottawa railway. The mica is a pale amber coloured phlogopite. Sheets 5 inches by 2½ inches in size from this locality were seen, but the deposit itself was not visited.

Township of Methuen, lot 15, *concession* VII.—On this lot, at the extremity of Brooks bay on Lake Kasshabog, mica occurs at what is known as the Lynn mine. This is a small excavation in some syenite dikes cutting the amphibolite. The syenite consists chiefly of reddish feldspar, and in places becomes coarse in grain, holding segregations or patches of mica, some of it white and some black in colour.

Black tourmaline is also present in the dikes, although it is not abundant. The light coloured or white mica is a muscovite, but both it and the black mica are rather small in size, and are traversed by cracks which would seriously interfere with their economic application.

Township of Methuen, lot 16, *concession* VII.—This deposit, on which is located what is known as Osterhause's mine, is very similar in character to that last mentioned. The amphibolite is cut by the same syenite dikes and masses, with pegmatitic development, the latter rock consisting, as before, of reddish feldspar, and two micas. Several openings had been made at the time the deposit was examined, the most promising being that in a vein or dike about three feet wide. All the mica was apparently of small size. (See Plate LXVI.)

The mica at the Bennets and Crofts mines in Methuen is a muscovite, enveloping in many places crystals and fragments of corundum. This so-called alteration is fully explained in that portion of the report dealing with the nepheline syenites.

PLATE LXVI.

Nepheline syenite hills, looking northwest from Osterhause's mica mine, lot 16, concession VII, township of Methuen

TALC.

From lot 9, concession V of Grimsthorpe township, some five miles N.E. of Linghams Flat, several tons of talc were extracted and shipped. The mineral occurs here in a vein practically vertical, cutting a dark green igneous rock, somewhat schistose in places. It has been opened to a depth of 12 feet, and shows a width of 14 inches at the top, which widens to 18 inches at the bottom. The contents of the vein is solid, foliated talc, white and green in colour. This deposit was worked spasmodically, until the discovery of a much larger deposit of compact talc situated near Madoc, which is much more accessible and easily worked.[1]

A specimen from this locality was examined in the laboratory of the Geological Survey a few years ago, and reported upon as follows:

"Talc occurs on lots 8 and 9 of concession V of the township of Grimsthorpe, Hastings county, Province of Ontario. Presented to the Survey by Mr. A. Moon.

Structure, foliated massive; lustre, pearly on the cleavage surface; colour, pale yellowish green; in thin laminæ transparent; specific gravity, 15·5°C., 2·65.

An analysis by Mr. Wait gave as follows: -

SiO_2	60·47
Al_2O_3	0·27
Fe_2O_3	0·78
FeO	2·04
NiO	0·50
CaO	0·16
MgO	29·84
Water at 100°C.	0·32
Water above 100°C. (direct estimation)	5·42
	99·78

GRAPHITE.

Graphite has been found widely distributed throughout the region covered by the present report, but no deposits of economic importance have yet been discovered. Several of the gneiss bands

[1] Notes by R. L. Broadbent, who visited the deposit in September, 1907.

occur in intimate association with the thick belt of crystalline limestone, which crosses the Monck road on lot 9 of the township of Monmouth. The largest of these graphitic bands, which has a width of one foot, is exposed on the road, as well as in the fields on either side of it.

Graphite also occurs at the southern end of lot 38, concession I of the township of Anstruther. Its mode of occurrence at this locality is peculiar. The lot is underlain by crystalline limestone, which is cut by a series of great pegmatite dikes. These are composed of quartz-feldspar, together with some tourmaline. In one of these the graphite is found. The mineral occurs disseminated in thin films or scales through the vein, associated in some cases with a pale yellow mineral, which occurs in groups of bladed crystals, often radially arranged. The original character of the mineral has not been determined, as it is now in a highly altered condition. The graphite frequently occurs enclosed in or enveloping this yellow mineral, but it is also found in the other constituents of the vein, and is sometimes found filling what are evidently lines of fracture traversing the rock. This graphite-bearing dike is about 35 feet wide, and a hole about 35 feet deep had been excavated in it, in search of graphite, at the time the deposit was visited. The mode of occurrence is such as to make it improbable that graphite can be profitably worked at this locality.

Graphite is also found on lot 30 of concession IV of the township of Glamorgan, on the property of Archibald McColl. The mineral here occurs in a white crystalline limestone, in the form of veins which vary greatly in width from place to place. This is probably due to movements set up in the limestone, after the development of the graphite veins. The largest vein observed had a width of about four inches, but a much greater width is said to have been attained by a vein which was here opened up some years ago in a shallow pit, which is now filled in. The graphite is exposed on the road which crosses the southern end of the lot, as well as in the adjacent fields.

Another occurrence is found on lot 32 of concession XIII of the township of Monmouth, near Wilberforce post-office. Here a hill composed of pegmatite rises to a height of about 100 feet above the surrounding drifted plain. On the south side of this pegmatite mass there is a narrow strip of crystalline limestone only a few feet in width, striking between west and northwest,

following the margin of the pegmatite intrusion and dipping south at a high angle. Through this limestone, graphite is in places abundantly distributed, and where at one point an opening has been made the graphite shows up very well. Although the body of limestone exposed is small, it could probably be followed beneath the drift which flanks it, and additional supplies of graphite be thus secured.

CORUNDUM.

Corundum, or crystallized oxide of aluminium, is the most important mineral from an economic standpoint which occurs in this area. Its origin and geological relations are discussed in that portion of the report treating of the nepheline and alkali syenites. It is splendidly developed along a belt of syenitic rocks, which are more or less continuous from Lutterworth on the southwest to Clear lake and beyond on the northwest, as also in a much smaller band in the township of Methuen.

In the northeastern part of the area covered by the Bancroft sheet there are a great number of corundum occurrences, but only those in the northeast corner of Carlow township have been developed and worked to any extent. These are principally in the townships of Faraday and Dungannon, Monteagle and Carlow, but not enough work has been done on them to enable one to judge of their real extent and economic importance.

Pending the appearance of the bulletin on corundum the following is a list of some of the localities which have been opened up, to some extent. Full descriptions of these deposits are contained in the reports of the Ontario Bureau of Mines, by Dr. W. G. Miller.

The Ontario Corundum Company (now the Ashland Emery and Corundum Company), own deposits in concessions XII, XIII, and XIV of Carlow township, in the western extension of the main corundum-bearing belt in which are situated the mines of the Canada Corundum Company in Raglan township. It is at this point, on lot 14, concession XIV of Carlow, that corundum was first discovered, where a "range of very high prominent hills ends somewhat abruptly in a steep cliff or precipice, composed chiefly of coarse flesh-red pegmatite, cutting a dark reddish or brownish gneissic rock, which on examination under the microscope, proves

to be a hornblende ganite-gneiss." (Summary Rep. for 1897). The corundum occurs disseminated in the pink pegmatite, and this is mined by open cuts, on lot 14, concession XIV, and lots 15 and 16, concession XIII of Carlow. The ore is roughly cobbed at the quarry, and further concentrated in a well equipped mill. The following description is taken from the fourteenth report of the Ontario Bureau of Mines.

"The two main buildings are the boiler-house and mill. In the former, a 125 h.p. boiler is installed to do all the drying by steam as well as to run the plant. The plant comprises five Blake crushers, one 9 by 15 inches, two 7 by 10 inches, and two 4 by 10 inches; two 'lightning' (impact) crushers or pulverizers; two rolls; dividers; magnetic separator—the Noble; seven Hooper pneumatic jigs; a dryer; a 75 h.p. horizontal engine; and electric lighting plant. The ore will be dried immediately on arrival from the mine and will remain dry thereafter."

On lot 5 (as nearly as could be ascertained), concession I of the township of Monteagle, corundum occurs disseminated in a gangue of coarse feldspar, which is found as a dike cutting a dark micaceous, schistose gneiss, the bands of which have a strike N.E. and S.W. and a high dip (75 to 80°) to the east.

The Canada Corundum Company has done some work on this property, opening a trench some 75 feet long, digging several prospecting pits, and putting in a few shots, all within a radius of a few hundred feet.

The corundum is found in a gangue of coarse crystals of feldspar-mica, with scattered crystals of apatite. There has not been enough work done on this deposit to judge if it could be profitably worked.

On lot 13, concession I of Monteagle township, corundum occurs sparsely disseminated in a vein of coarsely crystalline reddish feldspar, mixed with a small proportion of coarse mica, and hornblende. The vein cuts a gneissic rock, and is parallel to the banding of the enclosing rock. Some work was done on this deposit by the National Corundum Wheel Company, of Buffalo, consisting of an open cut, some 25 feet long, 20 feet wide, with a face about 15 feet high. It is said that a certain quantity of corundum was sorted by hand and shipped to the United States.

In the vicinity of the line between lots 6 and 7, concession XIV of Dungannon, a little work has been done on a coarsely

Fig. 1. Corundum quarry at Craigmont.

Fig. 2. Corundum mill at Craigmont.

crystalline vein containing feldspar, nepheline, and some scattered crystals of corundum. This vein cuts a banded gneiss of greyish colour. Only a few blasts were put in at this place, and the work done is not sufficient to judge of the economic value of the deposit, although a few fine crystals of corundum, measuring up to two inches in diameter, were noticed.

The following is a detailed statement of the concentration of corundum as practised at the large and modern mill at Craigmont, by Mr. D. G. Kerr, formerly manager of the Canada Corundum Co. (Can. Min. Review, vol. xxvii, No. 5, November, 1906, pp. 151-156.)

Mines.—There are two companies working on this belt of corundiferous rocks—the Ontario Corundum Company, in Carlow township, Hastings county, and the Canada Corundum Company, in Raglan township, Renfrew county; the last-mentioned company having taken over the well known Craig mine and other deposits, covering an area of 2,000 acres in the counties of Renfrew and Hastings. At present, the works are confined to Craigmont, where the crushing and concentrating plant is situated, and corundum ore is quarried from the southern face of the hill, 500 feet high. In some places considerable stripping of sand and gravel is done to a depth of 5 feet. At some points the corundum-bearing rock crops out, showing the corundum crystals imbedded in the rock and polished down level with the rock by glacier action. At other points, where the corundum bearing rock has been exposed to the weather, the corundum crystals stand out boldly. The mineral is quarried in a series of benches up the hill, the faces running from 1 foot to 15 feet thick, and it varies in richness from 8 to 17 per cent. There are rich zones in the dike running down diagonally southeast; in these zones, rich pockets of big nodules of almost pure corundum are found associated with crystals of white mica. Cutting through this deposit are a number of dikes carrying hornblende in the same form as the corundum crystals, and readily mistaken for corundum. This dike varies in thickness from 2 to 10 feet, when the corundum comes in again higher up the hill. In a series of little pockets of corundum-bearing ore, the width may run from 40 to 100 feet, and the ore is found in layers or in benches. The surface rock will, perhaps, be ore; beneath this is a thickness of barren gneiss-rock, varying from 1 foot to 6 feet; beneath this

occurs another layer of corundum-bearing ore, 3 to 4 feet thick; another layer of waste and corundum ore follows in succession, until a depth of 25 to 30 feet is attained. A granite rock occurs below, but it has only been penetrated in three or four places; at one place within a distance of 32 feet, no sign of corundum ore was found.

On the property of the Ontario Corundum Company, 6 miles to the west of Craigmont, the occurrence and composition of the dike are practically the same, with narrow bands of black micaceous schist and coarse pink pegmatite in the syenite. A rock-bluff is worked with a perpendicular face going in east on the dike, with an average of 10 per cent of corundum crystals in the face.

The following analyses of corundum crystals show the purity of the mineral:—

Sample	Alumina Al_2O_3	Ferric Oxide Fe_2O_3	Insoluble Matter	Loss on Ignition
I.	92·62	...	1·13	2·04
II.	93·29	0·36	.....	1·91
III.	94·72	0·32	.....	1·14

The assay tests are made for crystalline alumina and magnetic iron, also for loss on ignition. In clean corundum crystal a small percentage of iron, from 0·5 to 2 per cent, is found combined with the corundum.

On the property of the Canada Corundum Company, the mining is done in the usual way, by means of air drills and dynamite. The holes are drilled 14 and 15 feet deep, and a series of as many as twenty holes are sometimes fired off by means of the electric battery. A large quantity in big pieces is thrown down, and they are block-holed and bull-dosed with dynamite down to suitable sizes for handling by the cullers, as it is very necessary to cull or select the ore. The percentage of corundum does not run high enough to allow of milling all the ore coming from the mine, without sorting out the low grade, as the lowest grade of ore fed to the mill requires to be higher than the amount which is lost in the tailings; it is also necessary to prevent as much as possible large pieces of magnetite, iron pyrites, or hornblende, from going to the mill, as they are difficult to remove when concentrating to 95 per cent.

PLATE LXVIII.

Corundum mining at Craigmont

In the very fine fissures, thin splashes of molybdenite (running high in molybdenum sulphide) are found, but this ore does not occur in any quantity, enough for samples only. It is stated that there is a vein of molybdenite in the neighborhood.

The drilling of the corundum-bearing rock, either by hand or by rock drills, is not difficult; but the diorite or crystalline limestone offers greater resistance to fast drilling.

From the open quarries on the face of the hill, the ore is brought down in stoneboats and trucks by teams to the tramway, where it is loaded on to cars, carrying 3 to 4 tons. The cars run on a tramway into the top of the mill; before entering the mill the car load is weighed and an exact tally kept of the number of tons which go into the mill every day (in wet weather, an allowance is made for the moisture in the ore). The cars are drawn by horses, and can handle 150 tons in 10 hours.

Mill.—The mill is situated at the east end of the southern face of the hill on which the corundum ore is quarried. The tramway, already mentioned, comes from the weighing machine and enters at the top of the mill; the cars are of the flat-top type and tip on both sides into the bin below. The bin is square and flat bottomed, with a capacity of 400 tons. The shute for feeding the crusher is near the centre of the bottom of the bin, and comes out to the ore-crusher; and alongside this chute a man stands and feeds the crusher, which is of the Farrell type of Blake crusher, 15 inches by 24 inches, running at 250 revolutions per minute, and crushing down to 2½ inches. The ore, after being crushed, drops on to a Robbins conveyor belt, 18 inches wide and 85 feet long, travelling at a speed of 300 feet per minute, with 20 per cent of an elevation to the delivery end.

The stream of ore coming from the conveyor belt is divided into three, and fed by short chutes into three smaller crushers, two of them being the Farrell type of Blake crushers, 6 inches by 20 inches, and one a Gates gyratory type A crusher. These three crushers reduce the ore to ¾ inch and less, and drop it into another large bin underneath, of 400 tons capacity.

From the underside, at the face of the bin, the ore is fed into coarse rolls by means of a Challenge feeder, the ore dropping from the disc of the feeder into the screen chute and straight into the rolls; the screen taking out all fines allows the rolls to do better work. The Challenge feeder formerly stood below the centre of the

ore bin, and the ore was carried to the rolls by a belt conveyor; but this was discarded, owing to the amount of ore spilled, and to permit of the attendant getting to the back part of the rolls so as to tighten the springs.

The ore, after passing through the coarse rolls, drops down, and is divided between two trommels, 13 feet long and 3 feet in diameter, running at 20 revolutions per minute, sloping 1 inch to the foot, the screens having 4 millimetre holes. The undersize passes downward into the vertical elevator, and the oversize passes to two sets of rolls and then into the same elevator. The elevator is an india rubber belt, with buckets bolted on (the buckets being 18 inches long, 6 inches wide, and 6 inches deep), running at 350 feet per minute. All the crushed ore is raised by this elevator in the form of a watery pulp to the top of the mill, where it is divided into two sets of five trommels in each set. Each trommel, 3 feet in diameter and 13 feet long, making 20 revolutions per minute, and with a slope of 1 inch to the foot, is driven by a sheave pulley and rope drive on the oversize end.

The pulp enters the two coarse trommels, the first 6 feet being covered with screens perforated with 4 millimetre holes, 4 feet with 6 millimetre holes, and 1½ feet with 8 millimetre holes. All pulp passing through the 4 millimetre holes goes to the next trommel, that passing the 6 millimetre holes goes downward to two sets of double three compartment iron Hartz jigs; and that passing through the 8 millimetre holes passes downward through wooden spouting lined with steel plate to a set of double two-compartment wooden Hartz jigs. The oversize, from these two trommels, goes downward to the roll floor, and, being recrushed, comes back through the same elevators. The pulp passing through the 4 millimetre holes on the first set of trommels passes to the second trommels, covered for the first 6 feet with screens having 2 millimetre holes, the pulp passing through the 2 millimetre holes goes on to the next set of trommels, and that passing over the 2 millimetre holes is sized on the next 5 feet of the trommel with 2½ millimetre holes; the pulp passing through the 2½ millimetre holes is treated on six Overstrom tables; this size is a little large for these tables, but it is done in the meantime for lack of jigs. The oversize of the 2½ millimetre holes goes downward to a double three compartment iron Hartz jig. The pulp passing through the 2 millimetre holes on the second set of trommels then

PLATE LXIX

Corundum mill at Craigmont.

passes to a third set, of which the whole length is covered with screens having 1½ millimetre holes; the undersize goes to the next set of trommels and the oversize to three Overstrom tables. The fourth set of trommel screens has 1 millimetre holes, the undersize going to the fifth set and the oversize to the concentrating tables. The pulp passing through the fifth trommel and the ¾ millimetre holes goes into a V box, and (the heavy particles settling) is fed to a concentrating table, and the surplus water is run into the tail race. The twenty Overstrom and four Wilfley concentrating tables, the two sets of double three compartment iron Hartz jigs, and the double two compartment wooden Hartz jigs, are placed on the floor below the trommels. The screen area of the iron jig is 24 inches by 36 inches, and the screens are of the same sizes in the hole as the trommel which supplies the material, but the top of the screen has 1½ inches of oversize material for a head. The speed of the jigs is 220 revolutions per minute; for the fines, up to 170 revolutions per minute; for the coarser sizes, the stroke is ¾ to 1 inch.

The product of the jigs' first hutch goes to the finishing rolls on the roll floor below, where it is crushed and goes to bin; being finished in the crushing part of the mill: the second and third hutches of the jigs, not being so clean, go to the rolls again and are crushed finer; and, owing to the want of a separate elevator and screen, they have to go back into the main elevator, where, if fine enough, they go to concentrating tables, and if coarse, are returned to the jigs. Tests made on the product of the jigs showed that the first hutch cleaned it to about 50 per cent of corundum, and the second and third hutches to 35 or 45 per cent of corundum: that is, from an ore which carries 10 per cent of corundum and 6 to 7 per cent of magnetic iron. The tailings from the jigs showed a loss of 3 per cent, but, as they were much overloaded, this did not give a fair showing; and, no doubt, with ample jig capacity, the losses would be reduced by 50 per cent.

The following is about the average percentage of corundum in the end products:—

	Per cent.
Ore fed to mill	$10\frac{1}{2}$
Jig concentrates	50
Jig partial concentrates	40
6 millimetre screen, jig tailings	3
4 millimetre screen, jig tailings	3
$2\frac{1}{2}$ millimetre screen, jig tailings	3
Table concentrates	60
$2\frac{1}{2}$ to 2 millimetre, table tailings	2
2 to $1\frac{1}{2}$ millimetre, table tailings	2
$1\frac{1}{2}$ to 1 millimetre, table tailings	2
1 millimetre to zero, table tailings	2
Magnet tailings, coarse	7
Magnet tailings, fine	3
Average	5
Rewash table tailings	5
Total mill tailings	5

The corundum is cleaned to 90 or 95 per cent.

On the same floor as the jigs, are the Overstrom and Wilfley concentrating tables; and on an intermediate floor are six more Overstrom tables, to treat the middlings from the preceding Overstrom tables.

The losses from the concentrating tables vary from $1\frac{1}{2}$ to 2 per cent, principally carried off floating in the water; as, in the crushing of the corundum crystals, owing to the hardness and the strain which is required to crush it, a percentage of the corundum goes to very fine powder and floats off in the water. The product from the concentrating tables and the finishing rolls is spouted into a small elevator, which raises it to another trommel for sizing, before being run into storage tanks. No. 12 mesh is the size of screen on this trommel, and all coarser than this to No. 10 mesh is rejected, and goes back to the finishing rolls and is crushed smaller. The corundum concentrates are now deposited in the five storage tanks; they are also used as filter tanks to take off the moisture, and are fitted with a little false bottom for drainage. The corundum concentrates, which now run about 50 per cent of corundum, are then sent from the crushing department to the grading room.

In the crushing part of the mill, there are four sets of heavy rolls, 14 inches by 40 inches, with shafts, 10 inches in diameter, fitted with brass sleeves, which slip on to the shafts and take all wear. The roll-shells are made of Hadfield manganese steel, and do the work with very little wear, and the jaw plates on all the crushers are made of the same material.

The Gates rolls, 14 inches by 24 inches, crush the product from the second and third hutches of the jigs. Adjacent are the Colorado or finishing rolls, 6 inches by 30 inches. There is another set of smaller rolls, but they have not been set to work yet.

The intention, when this part of the mill was built in 1903, and finished in the beginning of 1904, was to crush everything in the rolls small enough to concentrate on the Overstrom and Wilfley tables. This was found to be impossible, owing to the high percentage of fines, and the large amount carried off in the tailings in the form of fine slimes; the demand for the very fine sizes is small, and they are not so easily cleaned as the coarser sizes.

The crushing part of the mill containing the above machinery is a building 145 feet long, 36 feet wide, and 85 feet high, with five doors. On the second floor is the machine shop, equipped with a lathe, drilling machine, and two small shearing machines worked by hand.

The engine house is equipped with a Corliss engine of 225 horse-power a Corliss engine of 125 horse-power, and an auxiliary engine of 20 horse-power.

The first engine transmits power by means of six cotton ropes, 1½ inches in circumference, to the main shaft on the same floor, for driving all the jigs and concentrating tables, the trommels and the large elevator in the top of the building; also driving all the grading machinery in the grader building by a rope-drive from the same shaft. The other six grooves on the engine pulley drive the main shaft for the roll floor by means of one continuous rope, with a tightener pulley and a balance weight. This arrangement is being taken out, as in the event of this rope breaking, all the machines on this engine are stopped until the rope is straightened out and replaced. This means a stoppage of several hours, whereas, if the ropes were all single drives, the breakage of a rope would cause no stoppage, as the other five would have sufficient power to drive the full load until the first stop, when another rope could be slipped on to it, having been prepared and spliced over the two

shafts. From the main shaft of the jig and table floor a rope drive goes back into the engine room to drive a small dynamo of 220 lights of 16 candle power capacity. The little auxiliary engine drives the dynamo by means of a belt and countershaft, in the event of any stoppage of the large engine, and at the same time it runs the machine shop for repairs.

The second engine, of 125 horse-power, runs the crushers and a small Root pump. The power is transmitted from the engine to the countershaft by a continuous manilla rope, 1½ inches in circumference, with a tightener pulley: this also is being changed to single ropes.

In the same room as the engines is a cross-compound air compressor, with intermediate and after coolers, condenser, and air receiver, having an air capacity of 1,700 cubic feet of free air per minute, and compressing it to 100 pounds per square inch, thus providing the quarries with sufficient air to run about thirty drills.

Steam is supplied to the engines from three return tubular boilers, 5 feet diameter and 18 feet long, with furnaces and flues built up with bricks. Wood fuel is used, dry pine, maple, birch, and poplar being the principal woods, the consumption amounting to 25 to 30 cords per 24 hours. The boilers are placed in a building apart from the mills.

The water to supply the crushing and concentrating part of the mill is pumped by a Root pump from the basement of the grader building, to a tank placed behind the first set of coarse rolls. This pump has a capacity of 1,000,000 gallons per 24 hours, and throws it against a head of 60 feet. From this tank, the water runs to the rolls, tables, jigs, and launders. A jet of water is used to feed the ore into the rolls, and to keep down any dust.

Grader building.—The grader building is 135 feet long, 60 feet wide, and 80 feet high. The concentrates are brought into this building by a conveyor, and dropped on to a dryer.

The double-decked dryer, made of iron pipes, 1¼ inches in diameter, is heated by exhaust and live steam. The wet concentrates are distributed from the conveyor upon a No. 4 mesh wire screen, through which the stuff as it dries drops on to a conveyor belt, thence to an elevator, and is raised to the top of the building. The stream of concentrates is then divided over magnetic separators, one being of the cone and the other of the drum type.

The concentrates contain 12 to 15 per cent of magnetic iron; the nonmagnetic concentrates go down to the spilter on the floor below, and the magnetic iron, containing 4 to 5 per cent of corundum, is dropped outside of the building for further treatment.

Roughing splitters, with three screens, divide the concentrates into three sizes: No. 1 takes all sizes, from 8 to 24 meshes inclusive, and sends them to No. 1 graders; No. 2 takes all sizes, from 30 to 70 meshes inclusive, and sends them to No. 2 graders; No. 3 takes all sizes from 80 to 200 meshes inclusive, and sends them to No. 3 graders.

The roughing grader gives sizes passing through the screens; No. 1 is divided into sizes 24, 20, 16, 14, 12, 10 and 8 is over-size; No. 2 into sizes 70, 60, 54, 46, 36, 30 and 24 is over-size; and No. 3 into 200, 180, 150, 120, 100, 90, 80 and 70 is over-size. These products all go into bins above the rewashing tables and Hooper air jigs. Steel wire screen-cloth is used, from 8 meshes to 30 meshes; and silk screen-cloth is used for all of the other sizes, from 36 meshes to 200 meshes.

The Hooper air jig is a good machine for concentrating dry-sized concentrates; it works well on concentrates from 24 meshes to 70 meshes, and gives four grades of produce from 50 per cent corundum, as follows: firsts, or heaviest portion, magnetite and pyrites which have escaped the magnetic separators are extracted and sent to piles outside the building; seconds, or lighter portion, is clean corundum 90 to 95 per cent pure; thirds, or middlings, are held for retreatment, until a quantity is accumulated; and fourths, tailings or waste carrying off 4 to 6 per cent of corundum. The clean corundum passes from the Hooper jigs to an elevator, which raises it to the top of the building.

Five Wilfley rewash tables are used for cleaning up the coarse and the fine sizes. The Wilfley tables, running at 250 revolutions per minute, treat the fines, and the Wilfley table treating the coarse sizes runs at 215 revolutions per minute; the coarse tables have a stroke of $\frac{3}{4}$ inch and the finest table a stroke of $\frac{3}{8}$ inch. The products are: firsts, on the high side of the table, a little magnetite and pyrites; seconds are clean corundum, 88 to 90 per cent; thirds or middlings are retreated on the same table; and fourths, tailings or waste containing 5 per cent of corundum.

The clean corundum from the rewash tables is carried to the second deck of the dryer, dried and dropped down to the conveyor,

taken to the clean elevator, and goes to the top of the building along with the corundum from the Hooper jigs; then it goes over the finishing magnetic separator, drops through the floor, and passes the final magnetic separator. The process leaves a corundum carrying from 1 to 2½ per cent of iron, in the form of combined iron in the crystal corundum.

The corundum leaving the magnetic separator goes to the finishing splitters, of the same type as those already mentioned. This last operation must be carefully effected, as the exact sizing is very important to wheelmakers and users of loose corundum.

From the finishing grader, the product drops into bins in the floor, from which it is drawn into bags containing 100 pounds. Samples are taken from all the sizes each day, before the bags are sewn up, and as soon as the results are sent from the assay office, the grade of quality is marked on each bag, and it is then ready to be sent to market.

Three grades are made to suit the wheelmaker. The vitrified wheel requires the highest grade, the silicate wheel takes the next grade, and the third grade goes to the cement wheelmaker and the polishing trade. The corundum for vitrified wheels varies from 90 to 95 per cent pure. The silicate or chemical wheel is made with silicate of soda as the binding material. The binding materials used in the cement wheel are shellac, india rubber, linseed oil, etc.

The cost of producing finished corundum, including mining, milling, concentrating, sizing, packing, office expenses, insurance, and general charges, has not yet been reduced below £8 ($40) a ton; but with a well equipped mill, crushing 150 tons per 24 hours of a grade of ore containing 10 to 12 per cent of corundum the cost should not exceed £6 to £7 ($30 to $35) per ton.

GARNET.

Crystals of garnet, usually about half an inch across, but in some cases an inch, or even more in diameter, occur thickly disseminated through a micaceous amphibolite on the east town line of the township of Cardiff, where this is met by the line between concessions VI and VII. There is a great body of the rock in question, and it is well exposed on the road running along the south shore of Paudash lake. The garnet is pink in colour, and occurs

PLATE LXX.

Corundum quarry at Craigmont

in the form of well defined crystals, somewhat flattened in the plane of the foliation of the enclosing rock. This rock is comparatively soft and easily crushed, and should permit of an easy concentration of the garnet if desired.

A great body of dark basic gneiss or amphibolite, rich in garnets, is also exposed on the north shore of Fish Tail lake, on lots 12 and 13, concession IX of the township of Harcourt. The garnets range in size from small individuals up to crystals an inch in diameter, and are distributed abundantly through the rock. (See also page 170).

APATITE.

As might be expected, apatite is found at various points throughout the region, but the inaccessibility of much of the district, together with the low prices prevailing, have prevented the shipping of the material, although considerable development work has been done in the township of Monmouth, to the northwest of Tory Hill station on the Irondale, Bancroft and Ottawa railway.

At Millar's phosphate mine, situated on lot 15, concession XI of Monmouth, the apatite occurs in masses up to a yard in width, associated with a coarsely crystalline aggregate of hornblende, pyroxene, black mica, calcite, and sphene, with a little pyrite. It is present in one of the large pegmatite dikes which are so abundant in this vicinity cutting the banded quartzite. The apatite is of the crystalline granular variety, and is either red or green in colour. Several tons of apatite which had been extracted lay by the side of the excavation, but all work had been given up. No definite information was available as to whether any shipments had been made.

Large crystals of apatite are found associated with crystalline masses of hornblende in veins of pink calcite, cutting a fine-grained gneissic rock, on lot 3, concession X of the township of Monmouth. The upper portions of the veins have been dissolved away, leaving crevasses which are now partially filled with soil, through which the apatite crystals are scattered.

So far as at present known, however, the quantity of the mineral is not sufficiently large to be of importance from a commercial standpoint, although its presence would serve to indicate

that larger occurrences might be discovered if the surrounding district were carefully prospected.

Small quantities of apatite also occur in association with granular green pyroxene and scapolite, in veins cutting rusty weathering gneiss, which occurs on this lot. A small amount of work has been done at this locality, but very little of the mineral could be seen, and but little has been shipped.

Apatite is also reported as occurring at the following additional localities: —(See also pp. 88 and 199).

Township of Dudley, lot 4, concession III.
Township of Dysart, lot 11, concession V.
Township of Harcourt, lot 21, concession XI.
Township of Monmouth, lots 14 and 17, concession XI.
Township of Cardiff, lot 8, concession XVI.
Township of Cardiff, lot 22, concession XIV.
Township of Cardiff, lot 22, concession XIX.
Township of Faraday, 5 miles southwest of Bancroft.
Township of Monteagle, lot 26, concession VI.

MARL.

Much attention has been directed to deposits of this kind because of the demand for this material in the manufacture of Portland cement. The material forming these deposits is made up of nearly pure carbonate of lime, with a greater or less admixture of impurities. These impurities are mainly silica and organic material, together with smaller quantities of other mineral matter, chiefly iron and aluminous oxides. When pure, it is white or pale cream in colour, varying in texture from very fine impalpable powder to rather coarsely granular, is loosely coherent, and dissolves readily with effervescence in acids, with very little residue. Although belonging to the present or post-glacial geological period, this marl is not always of very recent formation, as many beds of it are overlaid by deposits of peat or soil, the latter sometimes supporting a growth of forest of large trees. As a rule, however, these deposits are found covering the bodies of shallow lakes, ponds, or marshes, or the shallower places or bays of deeper and comparatively large bodies of water, and is very evidently still in process of deposition. The usually conspicuous and sometimes abundant presence of the shells of several species

of fresh water mollusks seemed amply suggestive in the first place, that such deposits had their origin, either wholly or in large part, in the accumulation of such calcareous shells, in a more or less fragmented condition, and hence the name shell marl so frequently applied. This was the first and simplest explanation. Other theories, although not denying the important fact played by such organic agency, hold that the ultimate source of this calcareous material was derived from the clays of glacial deposit, or contiguous masses of limestone. It has long been known that running water, with dissolved carbonic acid gas, is capable of taking up a considerable percentage of lime and other metallic salts, while recent investigations have shown that lime as the bi-carbonate is soluble to the extent of 238 parts in a million in water containing no carbon dioxide.[1]

This water, it was believed, issuing in the shape of springs and spring creeks which supply most if not all of these marl lakes, deposited a portion of the lime on reaching the surface, in the shape of a very fine powder, which forms so large a portion of these deposits. Recently, however, Mr. Charles A. Davis[2] of Alma College, Michigan, who has made very full and detailed investigations into the origin of the important marl deposits of Michigan, has come to the conclusion that "while some limited and rather small deposits of marl are possibly built up, or at least largely contributed to by molluscan and other invertebrate shells, the deposits, which are proving commercially valuable in the region under consideration, do not contain recognizable shell fragments in any preponderance, although numerous nearly entire fragile shells may be readily washed or sifted from the marl. The conditions under which marl is found are such that the grinding of shells into impalpable powder, or fine mud, by strong wave action, is improbable, if not impossible, for exposed shores and shallow water of considerable extent are necessary to secure such grinding action, and these are not generally found in connection with marl."

On the other hand, "if the amount of carbon dioxide contained in the water is considerable, some of it will escape on reaching the surface, because of decrease of pressure, and with its escape,

[1] Treadwell and Reuter. Ueber die Loeslichkeit der Bikarbonat der Calciums und Magnesiums. Zeitschrift fur Anorganich-Chemie, vol. 17, 1898, p. 170.

[2] Chas. A. Davis. A contribution to the Natural History of Marl. Jour. of Geol., Sept.-Oct., 1900, pp. 485-503, and Sept.-Oct., 1901, pp., 491-506

if the saturation point for the dissolved mineral matter has been reached, a part of this matter must be dropped in the form of a very fine powder as the water runs along over the surface. Theoretically, then, some, if not a great part of the dissolved matter, should be thrown down along the course of the spring centre, especially wherever there is slackwater. Moreover, we should expect the waters of these springs and streams to show more or less milkiness in standing exposed to the normal pressure of the atmosphere at usual temperature." It is, therefore, contended that some other cause or causes than the simple release from the water of the solvent carbon dioxide must be sought. After careful study and investigation it is shown conclusively that calcium carbonate is concentrated and precipitated by the agency of chara and other related algæ, and the author summarizes as follows in regard to the marl or lake lime deposits of Michigan: (1) That marl, even of the very white pulverulent type is really made up of a mixture of coarser and finer matter covered up and concealed by the finer particles which act as the binding material. (2) That the coarser material is present in the proportion of from 50° to 95°. (3) That this coarser material is easily recognizable with the unaided eye and hand lens, as the incrustation produced in the algæ, schizothrix and chara, principally the latter, to particles less than one one-hundredth of an inch in diameter. (4) That the finer matter is largely recognizable under the compound microscope as crystalline in structure, and is derived from the algæ incrustation by the breaking up, through decay of the plants, of the thinner and more fragile parts, or by disintegration of the younger parts not fully covered. (5) That some of this finer matter is capable of remaining suspended in water a sufficiently long time after being shaken up with it to make it unnecessary to advance any other hypothesis to explain the turbidity of the waters of some marl lakes, than that it is caused by wave or other agency. (6) That shells and shell remains are not important factors in the production of the marl beds which are of largest extent. (7) That there is in marl a small amount of a water-soluble calcium salt readily soluble in distilled water after complete evaporation. It is concluded by Mr. Davis that these algæ are the active agents in "the concentration of calcium salts in the fresh water lakes of Michigan, and that they alone have produced a very large part of the marl which has accumulated in these lakes. It seems

probable also that the principles developed by these studies are of very wide applications in working out problems presented by formations developed under similar conditions elsewhere."

Marl has been extensively used in the manufacture of Portland cement, and as a consequence attention was directed to the larger and more conveniently situated deposits. The chemical elements necessary for the manufacture of Portland cement are lime, silica, and alumina, the last two being generally supplied by some form of clay or shale, the average ratio being one part clay to four parts carbonate of lime. The lime used may be classified under three general groups,—argillaceous limestone, marl, and limestone. The last in the present order of output, but probably second in amount of capital invested and men employed, is marl.[1] For profitable working the marl should average at least ten feet.

It is sometimes used as a dressing for soil which is deficient in calcareous matter. When calcined, marl yields a nearly pure and very white lime, well adapted for mortar and other uses. When pure, marl may be used as a substitute for prepared chalk or whiting in cleaning metals, and for similar purposes. In many parts of the country it is commonly employed by the people for whitewashing their buildings.

It has also been used for the production of carbonic acid gas for the manufacture of soda, and other aerated waters, in place of the pulverized chalk or marble dust which is generally employed.[2]

Two important deposits of this kind have come under our notice in the examination of this region. The more extensive and important deposit is that which is still in process of deposition, covering the shores and the greater portion of the bottoms of the Blue Sea lakes, which form the head waters of the branches of Beaver creek, in concessions XII and XIII of the township of Limerick. The other deposits form the bottom of Snow lake, a sheet of shallow water which occupies almost the whole of lot 24, concession IX of the township of Wollaston. The depth of the marl was in neither case ascertained, but it is very evidently of such extent as to be available for economic purposes. The marl of Snow lake is overlaid by about four inches of sand.

[1] Henry S. Sparkman.—"Manufacture of Cement from Marl and Clay." Proc. Engineers Club of Phila., April, 1903, pp. 154 175.

[2] Geol. of Can., 1863, pp. 763 764.

It is in many places quite white and contains numerous little shells. A sample treated with dilute hydrochloric acid went into solution, leaving but a comparatively small amount of insoluble residue which shows that the deposits consist of carbonate of lime holding only a comparatively small percentage of impurities. At the Blue Sea lakes, shells of various species are conspicuous, and the following species collected were determined by Dr. J. F. Whiteaves:—

Sphœrium sulcatum (Lamrarck)
Posidium abditum (Haldimand)
Planorbis campanulatus (Say)
" bicarinatus "
" deflectus "
Physa ancillaria "
Valvata tricarinata "
Campilonia decisum "
Limnea galbana (?) "
Mesodon sp.? (Young) "
Succinea oralis

With the possible exception of limnea galbana, which is supposed to be extinct, all the above represent existing species. They are all freshwater shells, with the exception of the last two, which are land species.

MARBLE.

Owing to the extensive building of large edifices at present going on in Eastern Canada, such as government buildings, banks, public libraries, etc., the attention of architects should be drawn to the apparently unlimited supply of various marbles which can be obtained in this district. Only a few places have been opened for ornamental stone, but these examinations were sufficient to show that marbles of various colours and textures, equal to the best imported material, could be obtained in the region. Large blocks, free from flaws and shakes, suitable for columns of any size can be quarried, and as transportation facilities are adequate, stone could be put on the market in large centres, such as Toronto, Ottawa, and Montreal, at prices much lower than those obtaining for imported marbles.

On lots 1 and 2, concession XII of Faraday township, a great deal of work has been done in opening up a marble quarry, on the northern edge of the area of crystalline limestone immediately south of the extensive body of nepheline syenite near Bancroft.

The presence of good workable marble has here been proved, by pits and strippings, over an area more than half a mile long by some 1,000 feet wide. Stone can be obtained ranging from a coarse crystalline white marble to a greyish, dove coloured, fine-grained stone; varigated and veined marbles have also been uncovered in places by removal of the drift.

At the main working place of this quarry, a wide dike of igneous rock has slightly disturbed the beds, but nevertheless some very large blocks have been extracted; some of those, which were lying on the floor of the quarry, weighed up to 20 tons or more, without any apparent serious flaws. In other parts of the ridge the beds are lying in a very favorable position for working, the dip being generally very slight.

The Ontario Marble Quarries, Ltd., under the managership of Mr. Thos. Morrison, with a head office in Toronto, has secured two lots, Nos. 41 and 42 of the Hastings road (township of Faraday), and is opening up a marble quarry upon them. The work at the time that the property was visited, on July 2, 1908, consisted of stripping, and the preliminary opening up of a few faces in the rock. The drift covering the area is thin, and the rock outcrops at many places on the lots. The development of the property which has been carried out, shows that at least four distinct varieties of marble can be obtained in different parts of the area. These are distinguished by the company as follows:

1. "*Laurentian Vein.*"—This is a variety of fine-grained, nearly white marble, with a brecciated structure, there being elongated, more or less rectangular-shaped fragments of a white-grained marble cemented together with a darker material. The structure of the rock is often seen to have been developed by a series of minute and repeated faults. The rock is probably a fine-grained dolomite, since it has a brown colour on the weathered surfaces.

2. "*Laurentian Blue.*"—This marble is obtained from an opening in another part of the area. It is a fine-grained, bluish variety, in some cases traversed by white streaks.

3. "*Breche.*"—Of this rock there are lighter and darker coloured varieties. It is a true breccia, the fragments being usually of a pale white or cream colour, while the cementing matter is darker in colour. It differs from the Laurentian vein in that the fragments of the former are more oblong and rectangular in shape.

4. "*Rose Fantasia.*"—This is an irregularly banded and streaked marble, presenting a great variety of colours, some of which are wonderfully brilliant. Some bands are pale pink, some bright red, others white or cream coloured and coarsely crystalline, while still others are white and fine in grain. The brilliance of the colour of the red bands is especially striking.

The property is situated some two miles from the Central Ontario railway, and the contour of the surface is of such a character as to enable the various varieties of marble to be easily quarried.

A very complete quarrying plant has been installed by the Central Ontario Granite and Marble Co. This comprises, in the main, an 80 ton derrick, two channelling machines, steam drills, engine house, hoist, blacksmith shop, etc.

A spur, one and a half mile long, connects the quarry with the Central Ontario railway at Bancroft.

On lots 41 and 42, west of the Hastings road, in Faraday township, some marble deposits, owned by Messrs. Riddell and Morrison, were seen, which would yield a great variety of beautiful ornamental stone. On lot 41, along a ridge which has an elevation of some 100 feet above the valley of a small creek, working faces of 75 feet high by 300 or more feet long, could be established. The beds dip slightly to the west, the maximum inclination observed being about 20 degrees. They are in thicknesses varying from 3 to 6 feet or more. Very little work has been done at this place, but several large specimens have been extracted and polished for the purpose of testing the marble, and the results have been eminently satisfactory.

In this ridge the most prevalent varieties are a blue greyish stone, yielding a dove marble, and a yellowish limestone breccia, which gives on polished surfaces a beautiful mottled brecciated marble of a warm colour.

On the same lot, a few hundred feet east of this ridge, is another one, from which unlimited quantities of a pink, reddish marble,

mottled and veined, could be extracted; all of these stones take a high polish.

These deposits are favourably situated for working, as they could be reached by a spur of the Central Ontario railway, about 1½ mile long.

On lots 26, 27, 28, 29, and 30, concession X of Dungannon township, there are also large quantities of limestone, ranging in texture from coarsely crystalline to very fine-grained and compact, from which marbles of various shades could be obtained.

On lot 29, concession X of Dungannon, at the north end of the lot, there is a large body of an amphibolite calcareous rock, very compact, though in places having a schistose structure, which gives a dark green, mottled, and veined marble. This stone takes a high polish, is rich in colour, and seems eminently suitable for interior decoration.

Serpentine Marble.—A body of beautiful serpentine marble, eminently suitable for decoration purposes, is found on lot 13 of concession XIV of Lutterworth. The occurrence is described on p. 213. A block of this, which was handed to the Forsyth Granite Co. of Montreal, was found by them to be easily worked and to take an excellent polish. When polished, the stone presents a very handsome appearance, and would have been used by the company above mentioned for purposes of interior decoration in the Canada Life Assurance Company's building in Montreal, as well as in other large structures, had the stone been in the market.

A pure white marble of good quality has been worked to a very limited extent on lot 2, concession VI of the township of Glamorgan, and a number of monuments made from it may be seen in the cemetery at Gelert. There are also great bodies of marble which are excellently adapted for building and ornamental purposes, to be found in many widely separated parts of the area. A number of these occurrences are described on p. 195, in the section treating of the crystalline limestones of the area.

Much of the crystalline limestone in the township of Lutterworth constitutes a veritable marble, as on lot 19 of concessions IV and V, and on lot 20 of concession V. This limestone would yield excellent lime, and would afford a fine material for building stone. It is, however, rather coarse-grained for very fine work, or for statuary purposes.

SODALITE.

On lot 25, concession XIV of Dungannon, some considerable development work and quarrying have been done on a body of sodalite, which it is intended to work extensively for a decorative stone. This mineral, which has a beautiful blue colour, ranging from a dark shade to a very pale blue, takes a high polish, and is eminently fitted to be used as ornamental stone of high grade.

This deposit, which is situated some five miles east of Bancroft, occurs in the large body of nepheline syenite shown on the map. The presence of the sodalite has been proved over a length of some 250 feet, and a width of 40 to 50 feet on the side of a hill, and it is said to extend farther. Sufficient stone has been extracted to prove this to be a large workable deposit, and according to Mr. T. Morrison, who represents the owners, a shipment of 130 tons was made to England in 1906, the stone to be used in decorating the residence of Sir Ernest Cassell, Park Lane, Hyde Park, London. Blocks of considerable size can be extracted, weighing several tons. The intention of the owners is to install a complete plant for the quarrying of the stone, and sawing into slabs. The quarrying will have to be done with channelling machines, as blasting shatters the stone somewhat.

It may be remarked here that in this deposit of sodalite, more particularly near the edges where it merges into the nepheline rocks, there are patches of aventurine feldspar or sunstone, which can be polished and used as a semi-precious stone.

This exploitation is known as the Princess quarries, but the company has not been incorporated as yet.

Immediately south of the above, there is another occurrence of sodalite on lot 25, concession XIII, township of Dungannon. Very little work has been done here. The rock has been uncovered by stripping in six or eight places, and at several places the blue sodalite shows as patches in the nepheline syenite. A few blasts were put in, opening the rock over a surface of 15 x 20 feet, and several patches of the blue sodalite are visible. Not enough work has been done here to ascertain if the mineral is present in sufficient quantity to be quarried for decorative stone.

COMPARISON OF THE GEOLOGICAL RELATIONS OF THE AREA WITH THOSE OF OTHER DISTRICTS.

While in its physiographic character this area resembles all other parts of the Laurentian protaxis, except that which borders the Atlantic coast of Labrador, in which latter district the surface is much more accentuated, in its geological character the area bears a particularly close resemblance to that stretch of the Laurentian country which occupies the southern margin of the Laurentian protaxis from the Georgian bay to a point nearly as far east as the city of Quebec. A complete examination has not been made of all this country, but the work of Logan in the original Laurentian area, which is situated in the district about the county of Argenteuil, in the province of Quebec, and that of Adams in the continuation of this tract of country to the east; as well as the work of Vennor and Ells in the region between the county of Argenteuil and the Haliburton area, afford a sufficient basis for the recognition of the essential unity of the great limestone-bearing series which underlies the greater part of the area in question.

Farther south, in the state of New York, these ancient rocks again appear through the Palæozoic cover, occupying an area of. 10,000 square miles, and forming the Adirondack mountains. Here granite, anorthosite, and gabbro intrusions occupy a relatively greater proportion of the area, but remnants of the overlying sedimentary series (Grenville series) are found throughout the area in ever increasing abundance as it becomes more thoroughly examined. As has been already mentioned in the chapter dealing with the general geological relations of the Grenville series, the total area underlain by the series in question is not less than 83,000 square miles, it being one of the great limestone series of the continent. With a view to securing a satisfactory correlation and nomenclature for the whole pre-Cambrian development of this portion of the protaxis, upon the conclusion of the work in the area embraced by the present report, a special committee representing the Geological Survey of the United States and the

Geological Survey of Canada was formed for the purpose of visiting the various areas of these rocks, and reporting upon the correlation which could be made and the nomenclature which should be adopted.

This committee consisted of President C. R. Van Hise, Dr. J. F. Kemp, and Professor H. P. Cushing for the United States Geological Survey, and Dr. A. E. Barlow, Professor A. P. Coleman, and Dr. F. D. Adams for the Geological Survey of Canada.

This committee spent the month of July, 1906, in visiting various districts in the Adirondack mountains, and in studying typical sections of the area embraced by the present report, and when in Canada also visited the Madoc area, which lies to the south of map sheet 118. They also made a study of the work of Logan and Adams in the province of Quebec, although not actually visiting these areas.

At the conclusion of their work the committee made a report upon the various problems of correlation and nomenclature, in which the geological character and relations of this area are compared with those of the Adirondack mountains, and the original Laurentian area and its eastward extension. The full text of this report is to be found elsewhere.[1]

In order that a comparison may be instituted between the area described in this report and the other areas studied by the committee, the following extracts from the report of the committee are here given:

"So far as known, the oldest series of rocks in the Adirondack area consists of strongly and coarsely crystalline limestones, ophicalcites, quartzites, quartz-schists, rusty, micaceous, thinly foliated gneisses, and more massive gneisses. Amongst these the limestones are on the whole the ones most easily recognized. On the east they are well and prominently developed. In the central area they seem to be extensive, but are poorly exposed, and quartz schists are prominent. On the northwest they appear in largest amount, and form continuous belts over long distances. The limestones are usually charged with bunches and streaks of silicates, which are in part torn and sheared intrusives, in part

[1] Report of the Special International Committee on the Correlation of the pre-Cambrian Rocks of the Adirondack Mountains and "Original Laurentian Area" of Canada and Eastern Ontario. Jour. of Geol., vol. xv., No. 3, 1907. Also Summary Report of the Geological Survey of Canada for 1907.

pegmatites, and probably also in part former siliceous, ferruginous, and aluminous bands.

The quartzites on the east are best developed near South bay, one of the two southern arms of Lake Champlain. They are thoroughly recrystallized, and all original clastic structure has been destroyed. They may contain great proportions of feldspar, and may also have sufficiently large percentages of graphite to be mined for this mineral. These feldspathic varieties were doubtless originally shales.

Rusty micaceous rocks with a peculiar yellow colour on exposed surfaces are also frequent, although not in great thickness. They and other schistose, micaceous gneisses are believed to be recrystallized sediments.

Beneath the above, and sometimes interstratified with them, are more massive gneisses of a general granitic composition. While quartz and feldspar are the principal minerals, dark silicates also appear, of the following kinds: emerald-green augite, brown hornblende, and biotite. Several varieties of gneiss are known, depending on the relative proportions of these minerals. The iron ores are associated with them in almost all cases. It is a doubtful point as to whether these gneisses are in any cases sediments. They may be mashed, intrusive, granitic rocks in which the foliation is secondary, or they may be extreme phases in the metamorphism of arkoses or acidic volcanic tuffs.

In the Adirondack mountains the series is invaded by enormous bodies of intrusive rock (anorthosite, gabbro, syenite, etc.), so that the sedimentary portion of the series forms a relatively smaller proportion of the whole complex than in the other areas covered by the work of the committee.

The undoubted sediments, and their associated gneisses of uncertain origin, are penetrated by several varieties of plutonic eruptives. The oldest constitute the anorthosite series, and embrace rocks from aggregates of nearly pure plagioclase to fairly rich mixtures of augite, hypersthene, and ilmenite with the plagioclase. The borders of the great batholiths tend to be more basic than the centres.

The next in time among the intrusives constitute the syenite series. The typical rocks consist of microperthite, augite, hornblende, biotite, and varying amounts of quartz. Subordinate varieties are as rich in quartz as typical granites. Near the contacts with anorthosites and limestones garnets become numerous.

The third eruptive series consists of typical granites of both hornblendic and micaceous varieties. Areally the granites are of small extent, but they appear in scattered exposures outside the anorthosites.

The fourth series consists of dark basic gabbros, which are certainly later than the others, except perhaps the granites. No intersections with the latter are known. The basic gabbros appear in wide distribution throughout the area, and form dikes, stocks, and small laccoliths.

All these intrusives preceded a great period of metamorphism. Following it and still antedating the Potsdam, there entered two series of narrow dikes: one of basaltic rocks, which are very widely distributed, and a minor set of syenite-porphyry.

The oldest Palaeozoic sediment anywhere in the Adirondacks is the Potsdam sandstone.

From the above it is evident that in this area the pre-Cambrian formations are practically the same as those in the neighbouring parts of Ontario and Quebec.

It has been thought well to make reference here to the Original Laurentian area and to its easterly continuation to the north of the island of Montreal. The committee did not examine these districts, but the former was studied by Sir William Logan in the early years of the Canadian Survey, a map of it having been published in the atlas accompanying the report of the Survey for 1863, while the latter district was studied by F. D. Adams, his report and map of it appearing in 1896. As the studies in these districts have played an important part in shaping the nomenclature adopted in the case of the pre-Cambrian rocks of eastern America, the committee requested Dr. Adams to prepare the following brief description of them:—

The Original Laurentian area of Logan lies in the province of Quebec, on the north shore of the Ottawa river, between the city of Montreal and the city of Ottawa, and takes its name from the township of Grenville and the village of that name, which lie within it. The second area mentioned forms the continuation of this Original Laurentian area to the east, and embraces the district about St. Jerome and eastward nearly as far as the St. Maurice river. There is every reason to believe that the area embraced by these two districts represents the continuation of the pre-Cambrian series studied by the committee in eastern

Ontario, seeing that both occupy precisely the same relative position along the southern margin of the protaxis, and that rocks similar to them in petrographical character occur in the intervening tract of country. In the development of these rocks in the province of Quebec, however, the Hastings facies is absent, the rocks being all highly altered, and resembling in this way those found in the Adirondack mountains, and in the more altered portion of the Ontario district.

The Original Laurentian area and its easterly continuation [illegible] mentioned, like the area in eastern Ontario, occupy the southern portion of the Laurentian peneplain, underlying a great tract of slightly undulating country. They are composed of great bands of limestone, interstratified with amphibolite and rusty weathering gneiss, often highly garnetiferous. The rusty weathering gneiss, where it occurs typically developed in the district about St. Jean de Matha, is found to be rich in sillimanite, and to have the chemical composition of an ordinary [illegible] ite are also present in a number [illegible] with the gneisses and limestones above [illegible] Lime[illegible] however, is the dominant rock of the sedimentary [illegible]

In Logan's Original Laurentian area this distinctly sedimentary series occurs in great folds, the horizons marked by the limestone bands, as mapped by Logan, striking across the country in a series of great sweeping curves. The large bodies of orthoclase gneiss which are present in the district, and which Logan considered to form part of the sedimentary series, a more detailed examination in view of recent discoveries would probably show to belong to the lower igneous gneisses, and to be of intrusive origin.

Farther east, in the district to the north of the island of Montreal, the limestone series is not always so sharply folded, and in one portion of the district, over an area of about 750 square miles, it lies nearly flat, low quaquaversal dips being everywhere observed, the attitude of the beds suggesting that the whole series originally floated on a great body of the underlying granite series. This, farther north, comes to the surface, the limestone series being torn to pieces by it, and the batholiths thus emerging being traceable over great areas, the foliation of the gneiss presenting great sweeping curves, to which the courses of the lakes and rivers in this northern country conform. It will, therefore, be seen that in all its features this development of these pre-Cam-

brian rocks in the province of Quebec conforms to those which have already been described from the areas visited by the committee.

In the eastern part of the Original Laurentian area Logan found a large mass of anorthosite, which may be termed the Morin anorthosite. This formed the eastern limit of the area which he mapped. This anorthosite he found to be in some places more or less distinctly foliated, which foliation he regarded as a survival of an almost obliterated bedding. He furthermore found that the limestone bands in the sedimentary series disappeared on coming against this mass of anorthosite. From these two facts he concluded that the anorthosite belonged to an unconformable, though highly metamorphosed, sedimentary series, which unconformably overlay the Grenville series, whose limestones he considered to pass beneath the anorthosite mass.

Adams, in continuing Logan's work to the east, had occasion to map and thoroughly study this anorthosite body. He found it to have the shape of a clover leaf, and to have an area of 990 square miles. The anorthosite in the central portion, and over the greater part of the western half of the mass, is nearly massive, although often showing an indistinct brecciated structure. On going from the centre of the mass towards its eastern boundary, however, this brecciated structure becomes more and more pronounced, the angular fragments being imbedded in a progressively larger amount of granulated groundmass, while along the eastern border the mass becomes perfectly foliated, the angular fragments disappearing almost entirely. These angular fragments and the groundmass are identical in composition, both being composed essentially of plagioclase. The fragments represent portions of the original coarsely crystalline rock in an uncrushed condition, the groundmass being produced by the granulation and breaking down of the original rock, of which the brecciated fragments are the surviving remnants. The fragments in the breccia, like the rock when in a massive form, are deep blue in colour, while the granulated rock has lost this blue colour, and is grey, sometimes nearly white. This is due to the disappearance of the minute inclusions so abundant in the plagioclase feldspar of all these anorthosites which have not been crushed. Where the rock becomes perfectly foliated, as along the eastern border of the anorthosite mass, and especially in the narrow extension

running off from the southern part of the area and representing the stalk of the clover leaf, the rock becomes perfectly white in colour, so closely resembling a saccharoidal marble that the two can be distinguished only on making a trial of their hardness.

A detailed stratigraphical study of this mass proved undoubtedly that it was an igneous intrusion which had broken through the Grenville series, cutting off the limestone bands of the latter instead of covering them up, and which had been subsequently granulated by great pressure brought to bear upon the whole region from the east, seeing that it is on that side that the mass is most intensely granulated, while on the west, granulation is confined to the immediate border of the mass.

With regard to the petrographic character of this anorthosite, it may be stated that it is composed almost exclusively of labradorite: augite, hypersthene, and a little iron ore being the other constituents. It is identical in character with most of the other anorthosite masses in the Laurentian of Canada. Hunt, in his early investigations of these rocks, stated that three-quarters of the anorthosite occurrences in Canada did not hold over 5 per cent of minerals other than plagioclase.

It is to be noted that the foliation of the anorthosite, which is a secondary structure due to pressure, was already completed in pre-Potsdam times, for the perfectly foliated rock is overlain by horizontal beds of the sandstone in question.

In addition to this great intrusion of anorthosite, there are twelve smaller intrusions similar in character occurring in the area mapped by Adams.

In addition to these anorthosite intrusions, the sedimentary series in the original area, and in its extension to the east, is penetrated by several intrusions of more acid rocks. One of these consists of a mass of syenite, which occurs in the township of Grenville and has an area of about thirty square miles, which is in its turn penetrated by a small body of feldspar porphyry, sometimes holding a small amount of quartz.

Another acid intrusion is represented by the great body of granite, in places developed in the form of coarse augen gneiss, which occurs about twenty-five miles to the east of the Morin anorthosite intrusion. This possesses the ordinary character of such granitic rocks.

More especially in the southern portion of the Original Laurentian area there also occur a great number of basic dikes.

consisting for the most part of diabase, which represent, as a general rule, the latest intrusions of the district, and which persist across the front of the whole area from west of Grenville to a point north of the island of Montreal, where they disappear beneath the Ordovician cover. These diabase dikes were, however, considered by Logan to be older than the intrusion of syenite in the Grenville district already mentioned, which, in its turn, was older than the porphyry intrusion which cut it. While, therefore, in this Original Laurentian area, and its eastward extension, there is not so great a relative proportion of rocks which are clearly of intrusive origin as in the case of the Adirondack area, intrusive rocks in very considerable variety, and of the same general types, are represented.

It is worthy of mention that in the Laurentian protaxis still farther to the east, in the district to the north of the Gulf of St. Lawrence, and in the Labrador peninsula, a number of anorthosite intrusions of gigantic extent occur. Among these may be mentioned more especially one which may be referred to as the Saguenay anorthosite, on account of the fact that it is developed about the head waters of that river. This, which resembles the Morin anorthosite in character, has an area of not less than 5,800 square miles. Another enormous area is traversed by the Moisie river, the Clearwater, a tributary of the Moisie, running through a great canyon in this anorthosite. Still others of similar extent might be mentioned. The occurrences of anorthosite which are now known to exist in the Labrador peninsula represent a total area of nearly 50,000 square miles.

As a result of his studies in the Grenville region, Logan announced his belief that the Laurentian system consisted of two great unconformable series of sedimentary rocks, to which he gave the names Upper Laurentian and Lower Laurentian. The latter he considered to be again divisible into a lower and upper portion, which subdivisions he considered to be probably conformable to one another. In the course of time these several series came to be known respectively as the Anorthosite or Norian series, the Grenville series, and the Fundamental or Ottawa Gneiss. Logan's classification may thus be represented as follows:—

Upper Laurentian		Anorthosite or Norian Series.
Lower Laurentian	Upper portion	Grenville Series.
	Lower portion	Fundamental or Ottawa Gneiss.

The subsequent investigations by Adams in the district to the east of that studied by Logan showed that the anorthosite (or Logan's Upper Laurentian series), really consisted of great intrusions and that the associated limestones, etc., assigned by Logan to the Upper Laurentian were really part of the Grenville series. There, therefore, exist in these pre-Cambrian areas of the province of Quebec two divisions, namely, the Grenville series, and the underlying Fundamental Gneiss. The relations of these have not been worked out in such detail as in the case of the Ontario area, but it is believed that here also the fundamental gneiss comes against the Grenville series with an intrusive contact.

The international committee, to which reference has just been made, as a result of their studies reached the following conclusions, and made the following recommendations concerning correlation and nomenclature:

The committee considers that over the whole area covered by their investigations—namely, the Adirondack mountains, that portion of Eastern Ontario which they examined, the Original Laurentian area in the province of Quebec and its continuation to the east as far as the river St. Maurice—the pre-Cambrian sedimentary development is represented by one great series. This series is essentially identical in petrographical character throughout the whole region.

The only locality where the possible (Coleman would say probable) existence of a second unconformable sedimentary series was suggested by the facts observed was that on the Queensboro road, east of Madoc, Ontario. It is, however, still a matter of uncertainty as to whether the conglomerate here developed marks the base of an overlying, infolded, unconformable series, or not.

In Logan's original classification of the Laurentian this term—apart from the Upper Laurentian which was proved to be composed essentially of anorthosite intrusions—included two series differing in character, namely, the Lower Orthoclase (Fundamental) Gneiss and the Grenville series. Now that investigations have shown that these two series differ in origin, one being essentially a great development of very ancient sediments, and the other consisting of great bodies of igneous rock intruded through them, it becomes necessary to separate these two developments in drawing up a scheme of classification.

As the great intrusions of gneissic granite, forming what has been termed the Fundamental Gneiss, have an enormously greater areal development than the overlying sedimentary series, constituting as they do, a very large part of the whole northern protaxis, the committee recommend that the term Laurentian be restricted to this great development of igneous gneisses. The nomenclature suggested for the pre-Cambrian rocks of this eastern region will thus conform, so far as the use of this term is involved, with that suggested by the special committee for the Lake Superior region.[1]

For the overlying sedimentary series the committee recommend the adoption of the name Grenville series, as it is the name originally given by Logan to the series as typically developed about the township of Grenville in the Original Laurentian area on the north shore of the Ottawa river, in the province of Quebec, between the cities of Montreal and Ottawa. The term Hastings series, in the opinion of the committee, should be abandoned as a serial name, seeing that the development to which this name was applied by Logan is merely the Grenville series in a less altered form, as Logan in giving the name had conjectured was probably the case. The committee, however, think that it may in some cases be advantageously employed as a qualifying term to designate the less highly altered phase of the Grenville series, which may thus be referred to as the Hastings phase of the Grenville series.

In Canada this Grenville series everywhere, on going north, is invaded by and frays away into the great Laurentian batholiths, while in the Adirondacks it is cut to pieces by the great intrusions of that area, which, when worked out in detail, may prove also to have a more or less similar batholithic form.

The following succession in this region is therefore recognized and adopted by the committee:

Cambrian—Potsdam sandstones, etc.

(Unconformity).

Pre-Cambrian.

Grenville series.

(Intrusive contact).

Laurentian.

[1] See Journal of Geology, February-March, 1905.

The committee considers that it is inadvisable in the present state of our knowledge to attempt any correlation of the Grenville series with the Huronian or Keewatin, so extensively developed in the region of the Great Lakes. The Grenville series has not as yet been found in contact with either of these, and until this has been done, and the relations of the several series have been carefully studied, their relative stratigraphical position must remain a mere matter of conjecture."

In the southern portion of the Laurentian highlands, to the west of the area occupied by the Grenville series, that is to the north of Lake Huron, and in the district about Lake Superior, Rainy lake and Lake of the Woods, other pre-Cambrian series, differing essentially in petrographical character from the Grenville series, are found. These are, stated in ascending order, the Keewatin, Huronian, and Keweenawan series. Up to the present time the Grenville series has nowhere been found in contact with these, but it is hoped that the relations of these eastern and western pre-Cambrian developments may eventually be determined so that a correlation may be made between them. Until this has been done, however, their relations must remain a matter of mere conjecture. The two successions are as follows:

WESTERN DISTRICT.

Upper Cambrian	Potsdam Sandstone		
	Unconformity		
Pre-Cambrian (Proterozoic)	Keweenawan		
	Unconformity		
	Huronian	Upper (Animikie)	
			Unconformity
		Middle	
			Unconformity
		Lower	
			Unconformity
	Keewatin		
	Eruptive Contact		
Laurentian			

EASTERN DISTRICT.

Upper Cambrian—Potsdam Sandstone
Unconformity
Pre-Cambrian { Grenville Series.
(Proterozoic) { Contact Intrusive
Laurentian

While in some places great intrusions of the ordinary type preponderate, the striking batholithic development seen about the base of the series throughout the area described in the present report will, it is believed, when the mapping has been carried out in sufficient detail, be found to extend throughout the enormous area occupied by the Grenville series in Canada. This structure is already known to exist in this district to the north of the island of Montreal, and recent work in the Adirondack mountains shows that the same structure occurs there, in certain places at least.[1]

The same great development of batholiths as has been already mentioned (pp. 12 and 51), is found everywhere at the base of the Keewatin, and sometimes at the base of the Huronian in the district about the Great Lakes, which forms the continuation of the southern margin of the protaxis, to the west of the area occupied by the Grenville series.

It is a most striking fact that throughout this enormous stretch of country the actual base on which the oldest stratified rocks, whether they be epiclastic, pyroclastic, or sediments of the ordinary kind, have been laid down as wanting, unless the granite of the batholiths, as Lawson conjectures, represents this floor in a refused condition. It is, further, of great significance, as well as of great interest, to note that similar great intrusive batholiths of granite are found at the base of the sedimentary series in so many other widely separated parts of the earth's crust.

The granitic axis of the Alps is a post-Carboniferous intrusion, and it does not represent, as was formerly supposed, the actual basement on which the overlying sediment was deposited.[2] In the Aarmassiv the central granitic core has the form of a series

[1] Cushing, H. P.—Private Communication, November 10th, 1906.
[2] Weinschenk.

of batholiths linearly arranged over a distance of 100 kilometers.[1] The Saxon Granulitgebirge[2] is now recognized to be a denuded batholith.

Similarly the granitic axis of the Himalayas has been shown to be intrusive in origin,[3] while the enormous batholiths which occur at intervals along the whole length of the Cordilleran region from the Yukon valley to Mexico, and even on into South America, are of late Palæozoic, Mesozoic, or Tertiary Age.[4]

The floor on which the Cambrian strata in the vicinity of Boston were deposited has utterly disappeared, having been destroyed during the development of the granite batholith of the Blue hills south of that city, which absorbed by melting or solution not only the whole of the sub-Cambrian crust but a great volume of Cambrian strata.[5]

The facts seem to suggest that in all areas of great uplift the immediate cause of the upward movement is the rising of such intrusive masses in the earth's crust, so that the probability of finding at any accessible portion of the earth's surface the original basement on which sedimentation was inaugurated is somewhat remote. This uprising through batholithic intrusions so excellently displayed in all its details on the margin of the Canadian protaxis where the movement was completed in pre-Cambrian times, has evidently continued through all later geological ages—Palæozoic, Mesozoic, Neozoic—in regions of marked uplift, and is in all probability still in operation at the present time.

In its petrographical character, and in the display of the products of metamorphism which it presents, this great area on the southern border of the Canadian protaxis shows many resemblan-

[1] Baltzer, A.—Die Granitischen Intrusivmassen des Aarmassivs. Neues. Jahrb. fur Min.-Beilagebd. xvi., 1903, p. 292.

Baltzer, A.—Die Lakkolithen der Berner Alpen—eine neue Ansicht uber die Natur der Alpiner Granitkerne-Mitt. der Nat. Gessell. Bern. 1903.

[2] Credner, H.—Die Genesis der Sachischen Granulitgebirge-Centralblatt fur Min. &c. 15 April, 1907

[3] Middlemass, C. S.—The Geology of Hazara and the Black Mountain Mem. Geol. Survey of India, Calcutta, 1896.

McMahon, C. A.—Geol. Soc. of London, vol. 55, May, 1899.

[4] Daly R.—The Okanagan Batholith. Bull. Geol. Soc. Am. The Cascade Mountain System. Bull. Geol. Soc. of America, vol. 17, 1906

Kemp, J. F.—Ore Deposits, p. 375.

Lawson, A.—The Cordilleran Mesozoic Revolution. Jour. Geol., 1893, p. 597

[5] Crosby, W. O.—American Geologist, 1900, p. 301

ces to certain classical localities of the Grundgebirge on the continent of Europe,[1] but in none of them, with the possible exception of the Scandinavian peninsula, can the successive stages of the metamorphism be so clearly traced, or its final products be studied in such enormous development. The area is very instructive as presenting a section of the deeper portions of the Appareils Granitiques, laid bare to our sight by the processes of denudation.

The Laurentian protaxis from early times has been relatively an area of progressive uplift, while that of the great plains to the south forms an area of progressive sinking, since upon it has been deposited in successive stages, one after the other, a series of great systems of sedimentary rocks.

Here, along the border of these two great geological units, the deep erosion reveals, it would seem, the mechanism of elevation, the granite magma rising from the depths, and in all probability passing out from beneath the subsiding area to the south, lifting the old Laurentian Highlands, as the liquid in the Brahma press lifts the ram when the piston sinks. This upward motion probably was not, taking the Highlands as a whole, continuous or complete at one time, but was progressive, and repeated at successive periods. The texture of the granite constituting the batholiths in the area embraced by the present report shows that the movement, originating when the rock was a fused magma, continued as this cooled, and was filled with abundant products of crystallization, becoming at the same time more viscous and resistant to motion the movement being brought to a close only by the complete solidification of the rock. Further uplifts would probably be brought about by the intrusion of other masses.

There is here present also an excellent opportunity to study the action of the great bodies of deeply buried granitic magma, while highly heated and under great pressure, upon the invaded rocks. A certain amount of stoping undoubtedly took place, for the granite contains very numerous fragments of the rock it penetrates, which have been floated off from the sides and roof of the batholiths. That these have sunk deep down into the masses of granite is shown by the fact that in the northern portion of the area, where denudation gives a progressively deeper and deeper section into the heart of the batholiths, these inclusions every-

[1] Sauer, A. Das alte Grundgebirge Deutschlands, &c. Comptes Rendus ix. Congress Geol. Internat., Vienne, 1903, and other papers.

where persist. The inclusions in question, however, are basic, while the granite is acid, and the streaks and masses of grey gneiss which are found in the red gneiss, may, as has been said, represent the products of solution of certain of the basic inclusions in the acid invasion. These, however, do not constitute more than about ten per cent of the whole volume of the batholiths, while the basic inclusions do not exceed another ten per cent, so that the space now occupied by the batholiths was probably not developed altogether by a process of stoping and assimilation. The overlying cover was elevated and denuded, while the granite at the same time stoped out a portion of its lower surface during the process of elevation.

But hand in hand with this mechanical action, chemical changes were going forward, the character of some of which is clearly revealed, and the nature of others indicated by a study of the area. It is evident, in the first place, as has already been shown, that the invading granite under deep seated conditions has, in many places, at least along its border, changed the invaded limestones into amphibolites and pyroxene gneisses. The resulting products are similar to certain varieties of the Roche Dioritique described by Lacroix as produced by the action of the granite upon limestone in the Pyrenees.[1]

The most striking result of this action is that the granite, while everywhere breaking through the limestones, always holds inclusions not of limestone but of amphibolite. This change, however, is one which, so far as can be learned from a careful study of the area, does not extend beyond the immediate border of the granite intrusions. The bodies of amphibolite, occurring so abundantly elsewhere in the area, have undoubtedly in some cases, and probably in almost all cases, originated in other ways. While, therefore, the metamorphic changes induced by the granite in this area present certain marked analogies to those described by Lacroix from the Pyrenees, their study does not support the view put forward by him that granitic intrusions are merely great areas of shale or other sedimentary rocks changed *in situ* into granite, as presented in the following words: —"Je considère donc

[1] Lacroix, A.—Le granite des Pyrénées et ses phénomènes de contact. Bull. des Services de la Carte Géol. de la France, No. 64, p. 60; also Adams, F. D. The Excursion to the Pyrenees in connection with the Eighth International Congress. Jour. of Geol., vol. ix, 1., 1901

toutes ces couches métamorphiques isolées aujourd'hui au milieu du granite comme le résidu non digéré des assises sédimentaires dont à pris la place."[1] "La mise en place du granite s'est effectuée par dissolution graduelle des roches sédimentaires dont il occupe la place."[2]

The origin of the nepheline syenite so extensively developed in the Bancroft region is also, as has been shown, in some way connected with the granite intrusions. It is a differentiation phase, or a product of the magma in question, and is almost invariably associated with limestones, which are in some way genetically connected with it. It is worthy of note that in Professor Lacroix's area in the Pyrenees, nepheline syenite also occurs, although here in smaller amount, and under such conditions that it is impossible to determine its actual genetic relations.

---

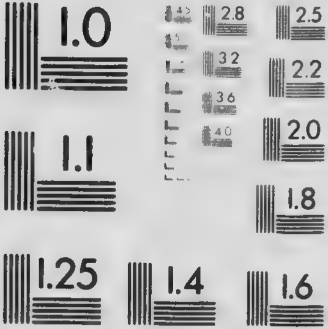
[1] Lacroix, A. —Livret Guide (Pyrenees Excursion), p. 65.
[2] Lacroix, A. —Le granite des Pyrénées, &c., p. 3.

INDEX.

A

MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No 2



APPLIED IMAGE Inc

D

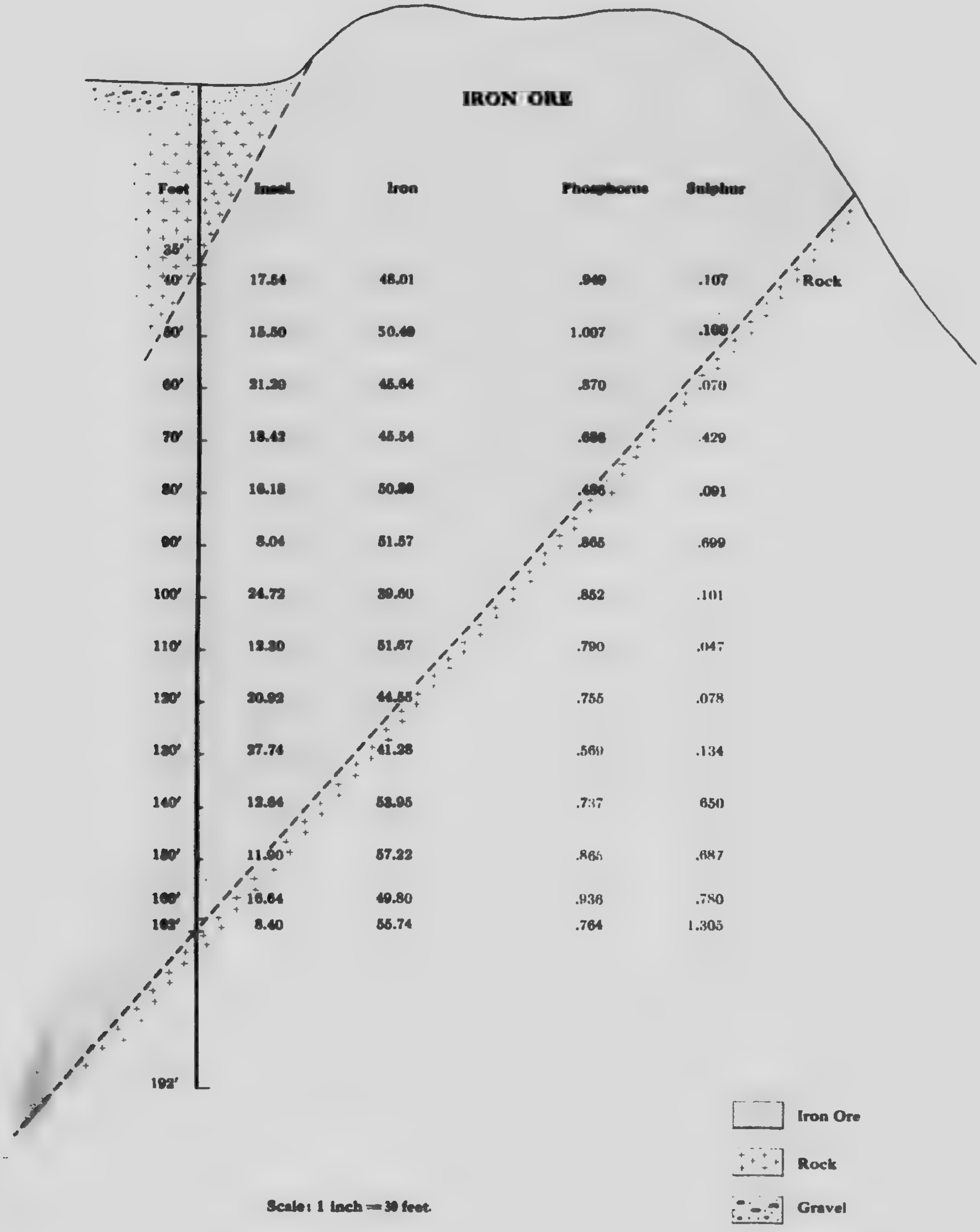
E

F

G

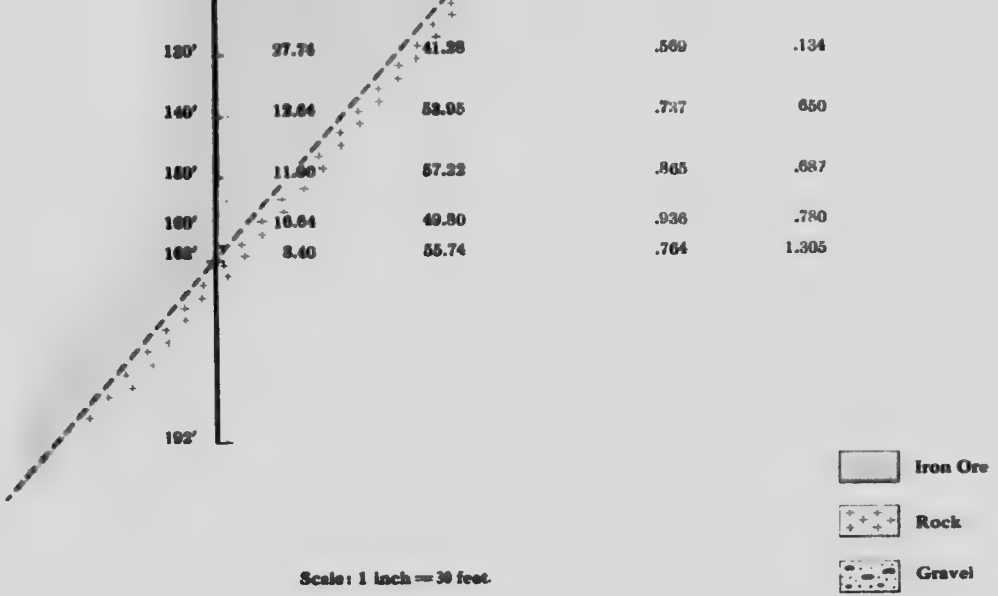
PAGE

DIAMOND DRILL HOLE No. 1



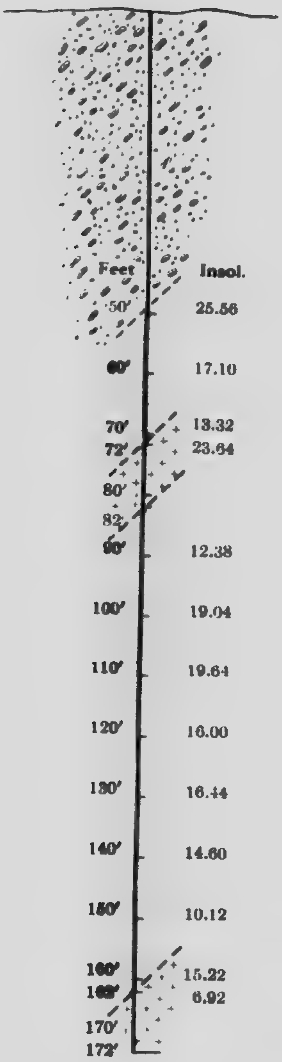
Feet	Insol.	Iron	Phosphorus	Sulphur
35'				
40'	17.54	48.01	.949	.107
50'	15.50	50.40	1.007	.108
60'	21.20	45.64	.870	.070
70'	18.42	45.54	.686	.429
80'	16.18	50.80	.486	.091
90'	8.04	51.57	.865	.699
100'	24.72	39.60	.852	.101
110'	12.30	51.67	.790	.047
120'	20.92	44.55	.755	.078
130'	27.74	41.28	.569	.134
140'	12.64	53.95	.737	650
150'	11.90	57.22	.865	.687
160'	16.64	49.80	.936	.780
162'	8.40	55.74	.764	1.305
192'				

Scale: 1 inch = 30 feet.

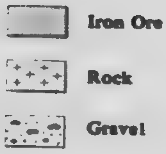

120'
27.74
41.28
.569
.134
140'
12.64
53.05
.737
650
150'
11.60
57.22
.865
.687
160'
10.64
49.80
.936
.780
168'
8.40
55.74
.764
1.305
192'
Iron Ore
Rock
Gravel
Scale: 1 inch = 30 feet.

120′	30.92	44.55	.755	.078
130′	27.74	41.28	.569	.134

DIAMOND DRILL HOLE No. 2



Feet	Insol.	Iron	Phosphorus	Sulphur
50′	25.56	49.86	.740	.035
60′	17.10	58.12	.552	.152
70′	13.32	58.70	.700	.026
72′	23.64	49.68	.912	.170
80′				
82′				
90′	12.38	44.46	.832	.268
100′	19.04	51.69	.600	.274
110′	19.64	50.08	.880	.040
120′	16.00	48.26	.716	.194
130′	16.44	50.08	.708	.096
140′	14.60	52.00	.972	.580
150′	10.12	45.05	1.060	18.21
160′	15.22	35.00	.528	31.97
16[illegible]′	6.92	44.05	.500	37.08
170′				
172′				



Scale: 1 inch = 30 feet.

Explanation of Colours and Signs
Nepheline syenite and allied alkali syenites
Conglomerate
LIVINGSTONE
HAVELOCK
HALIBURTON
GUILFORD
LUTTERWORTH

ological Survey of Canada

ROBERT B... M.D., LL.D., F.R.S., I.S.O. ACTING DIRECTOR

To accompany Parts H and HH Annual Report Vol XI

PROVINCE OF ONTARIO

Parts of Counties of Hastings Haliburton Renfrew and Nipissing

Haliburton Sheet

Natural Scale $\frac{1}{253440}$

Scale 4 miles to 1 inch

Miles

To illustrate Report of

FRANK D. ADAMS, Ph.D., and ALFRED E. BARLOW D.Sc.

Sources of Information

Instrumental surveys by Messrs A.E. Barlow, J. Keele, J. White, A.A. Cole and L.N. Richard of the Geological Survey
Plans of surveys by the Department of Crown Lands of Ontario

N° 708

Price 10 cents

Explanation of
Colours and Signs

Cambro Silurian

Black River

Archaean

Blue limestone

White crystalline limestone

Limestone and granular amphibolite

Limestone and "Feather" amphibolite

Limestone invaded by much granite
Contains admixture of amphibolite

Gneiss probably altered sedimentary material or quartzite

Gneiss (sedimentary) invaded by much granite

Conglomerate sandstone and arkose

Claystones often siliceous and calcareous with admixture of volcanic material

Amphibolite and gneiss bands

Amphibolite

Gabbro and diorite

Gneissic granite with many amphibolite inclusions

Granite massive

Gneissic granite

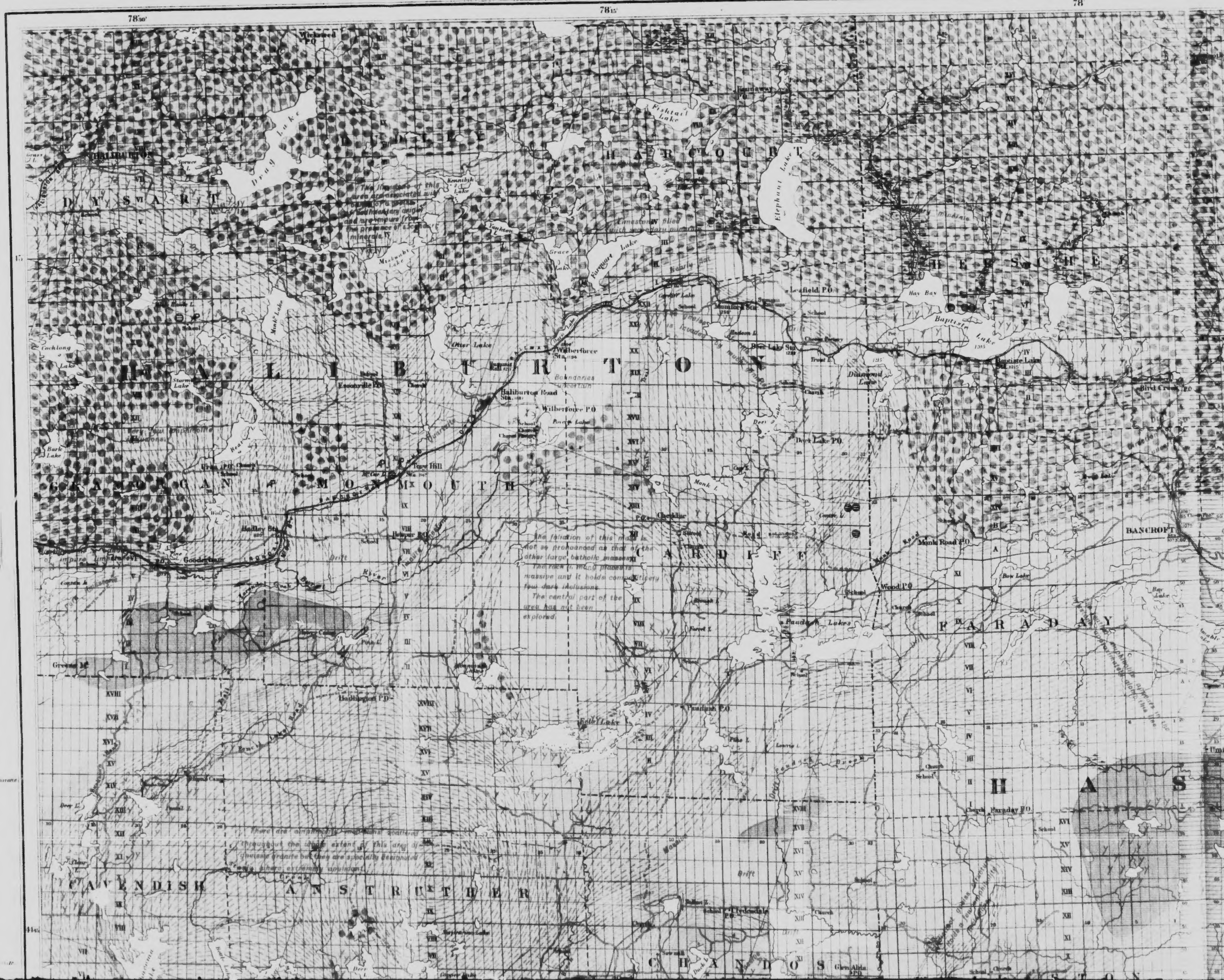
Pegmatite dykes

Acid volcanic rocks felsite etc

Nepheline syenite and associated alkalic rocks

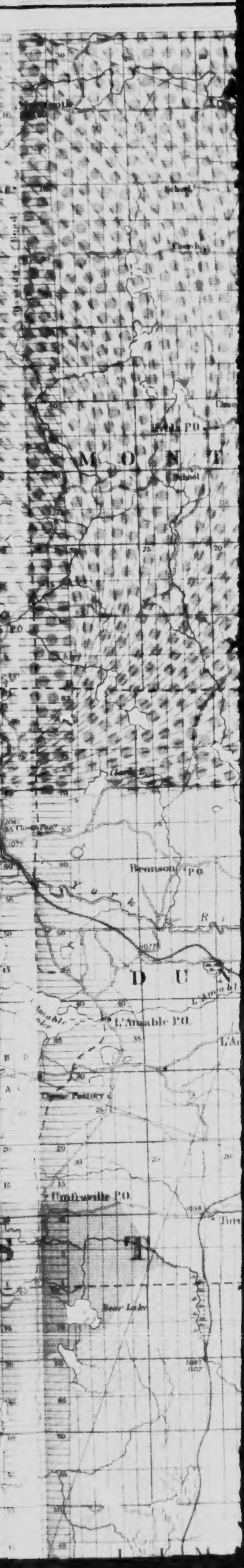
Geological Survey of Canada

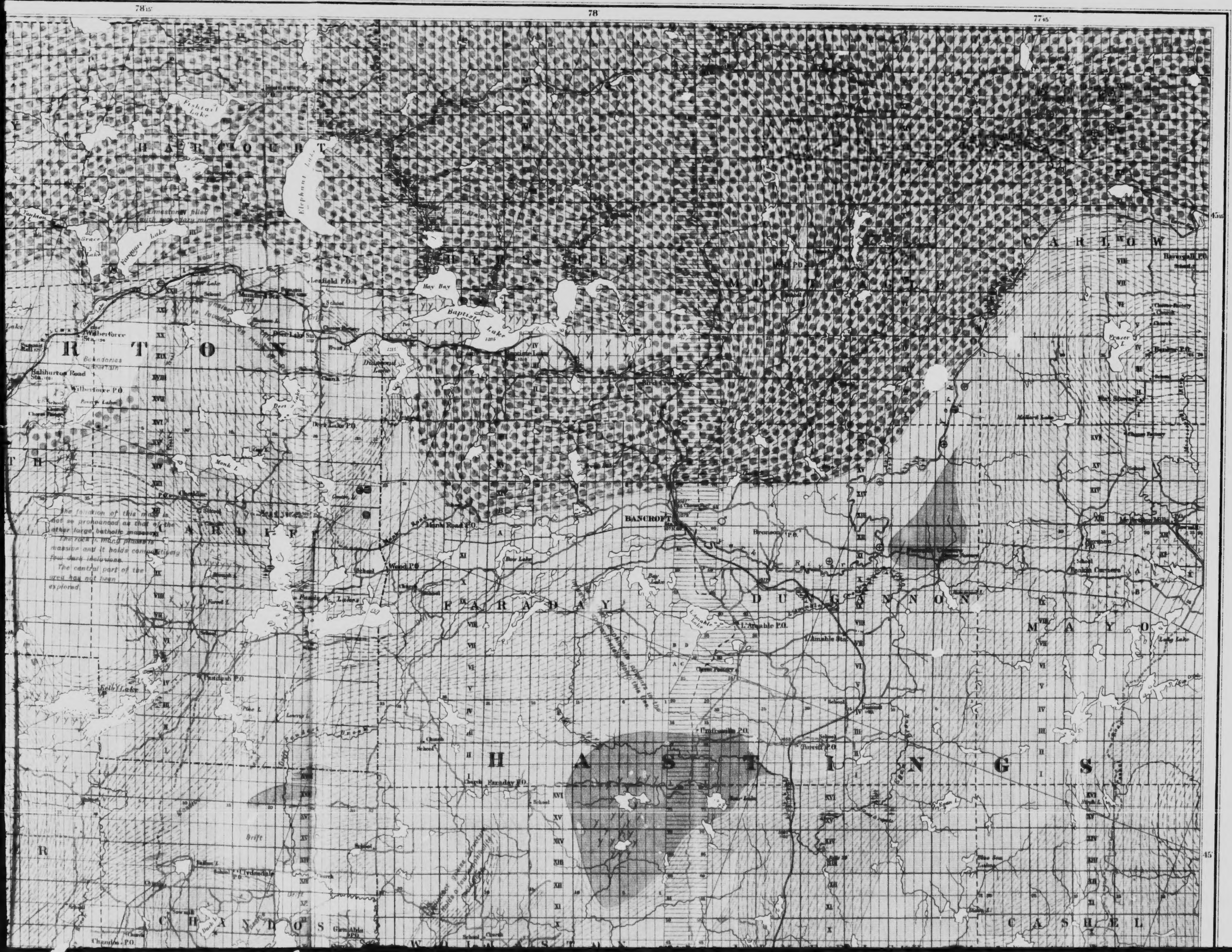
ROBERT BELL, D.Sc., M.D., LL.D., F.R.S., I.S.O., ACTING DIRECTOR

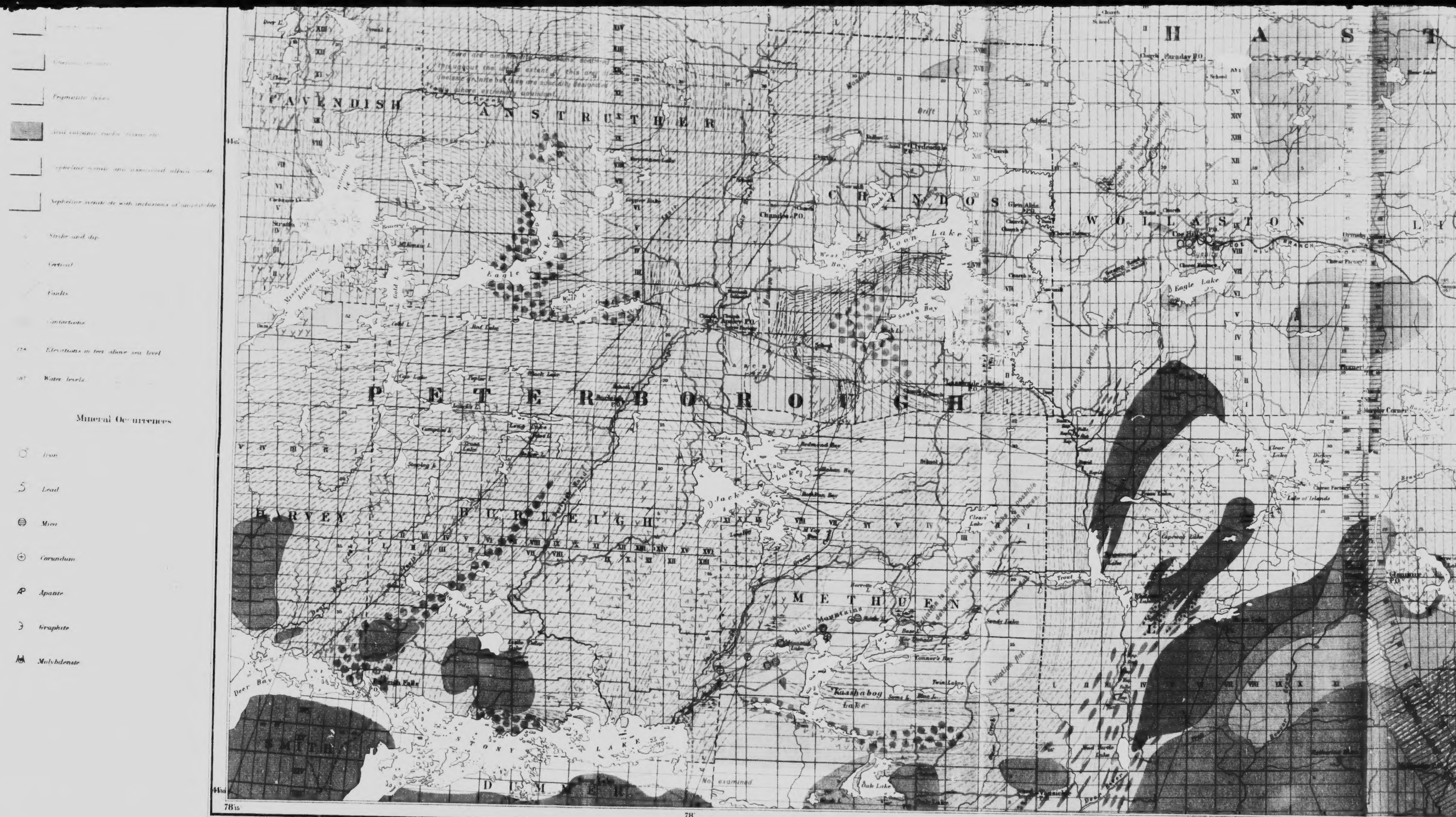


Geological Survey of Canada

ROBERT BELL, D.Sc. M.D., LL.D., F.R.S., I.S.O. ACTING DIRECTOR





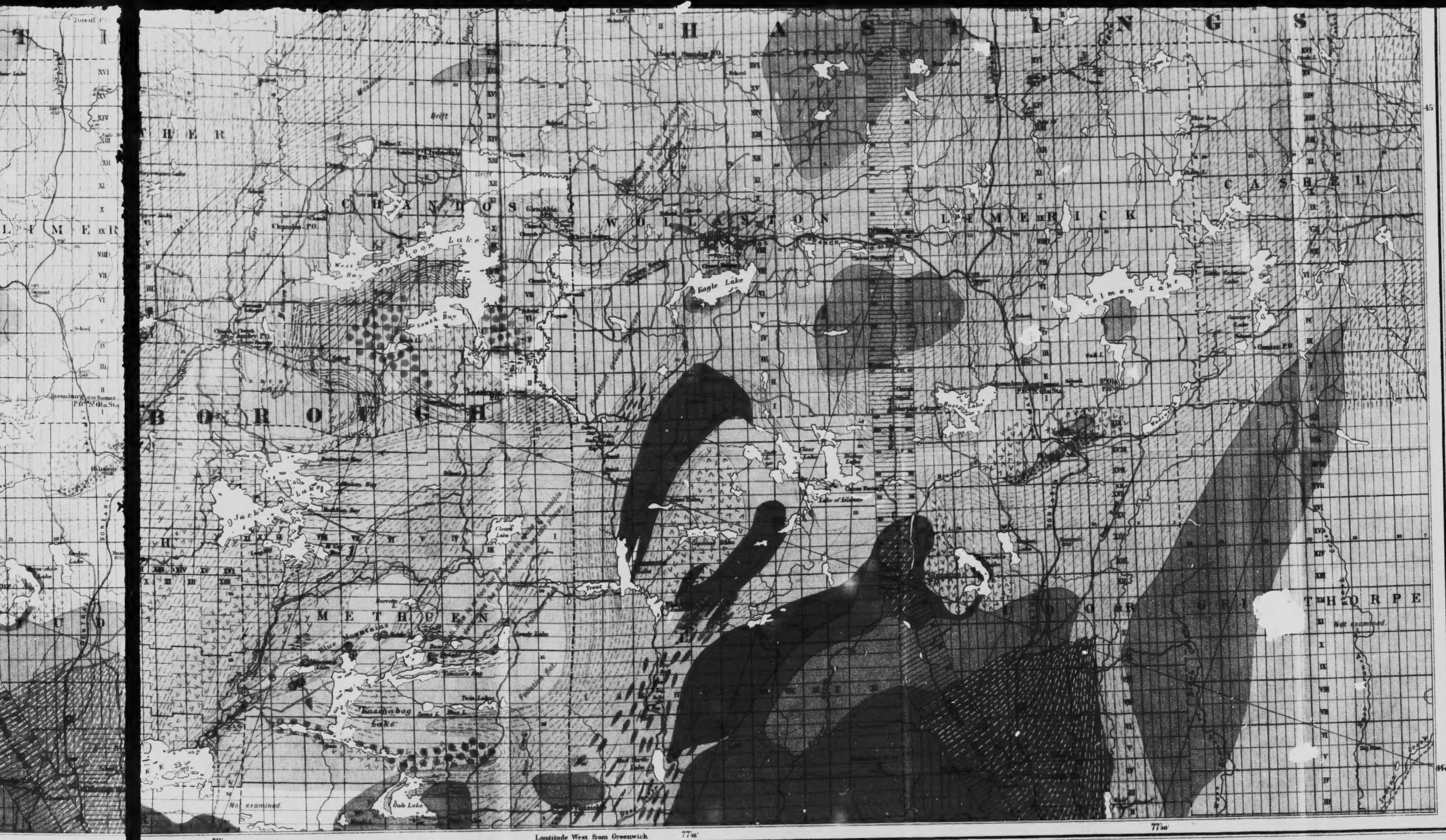


C.O. Senecal, B.A.Sc. Geographer & Chief Draughtsman.
J. Keele & L.N. Richard, Draughtsmen.

Magnetic Declination 8° to 9° West

GEOLOGICAL MAP
of portions of
HASTINGS, HALIBURTON and PETERBOROUGH COUNTIES.
PROVINCE OF ONTARIO.
(Bancroft Map)
by
FRANK D. ADAMS, Ph.D. and ALFRED E. BARLOW, D.Sc.

Scale, 2 statute miles to 1 inch = $\frac{1}{126,720}$



GEOLOGICAL MAP

of portions of

HASTINGS, HALIBURTON and PETERBOROUGH COUNTIES,

PROVINCE of ONTARIO.

(Bancroft Map)

by

FRANK D. ADAMS, Ph.D. and ALFRED E. BARLOW, D.Sc.

Scale, 2 statute miles to 1 inch = $\frac{1}{126,720}$

Sources of Information

Instrumental surveys by Messrs. A.E. Barlow, J. Keele, J. White, A.A. Cole and L.N. Richard of the Geological Survey. Plans of surveys by the Department of Crown Lands of Ontario.

Nº 770

Price 10 cts.

Second Edition